AFRL-IF-RS-TR-1998-5
Final Technical Report
March 1998

AVIONICS/ELECTRONICS QUICK RELIABILITY ASSESSMENT TOOL

Honeywell, Inc.

G. Havey, S. Lewis, and G. Seifert

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AIR FORCE RESEARCH LABORATORY
INFORMATION DIRECTORATE
ROME RESEARCH SITE
ROME, NEW YORK

Although this report references the following limited diskettes, no limited information has been extracted:

QRAT Software - diskettes (containing source code.) by Honeywell, Inc., Dec 93, Distribution limited to U.S. Government Agencies

This report has been reviewed by the Air Force Research Laboratory, Information Directorate, Public Affairs Office (IFOIPA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public, including foreign nations.

AFRL-IF-RS-TR-1998-5 has been reviewed and is approved for publication.

APPROVED: Mark E McCallum

MARK E. McCALLUM
Project Engineer

FOR THE DIRECTOR: Northup Fowler

NORTHUP FOWLER, III, Technical Advisor
Information Technology Division
Information Directorate

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
March 1998

3. REPORT TYPE AND DATES COVERED
Final Sep 91 - Feb 94

4. TITLE AND SUBTITLE
AVIONICS/ELECTRONICS QUICK RELIABILITY ASSESSMENT TOOL

5. FUNDING NUMBERS
C - F30602-91-C-0083
PE - 62702F
PR - 2338
TA - 02
WU - 4T

6. AUTHOR(S)
G. Havey, S. Lewis, and G. Seifert

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Honeywell Technology Center
Honeywell Inc.
3660 Technology Drive
Minneapolis MN 55418

8. PERFORMING ORGANIZATION REPORT NUMBER
C950805

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFRL/IFTD
525 Brooks Road
Rome NY 13441-4505

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFRL-IF-RS-TR-1998-5

11. SUPPLEMENTARY NOTES
AFRL Project Engineer: Mark E. McCallum, and later Roy F. Stratton/IFTD/(315) 330-3004

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This report describes the Quick Reliability Assessment Tool (QRAT) developed under this effort. The QRAT is a configurable data acquisition device designed to collect, process, and store environmental data for military and commercial electronic systems. It is designed for easy transfer from one platform to another, and to operate on its own battery, independent of the platform. The battery is considerably larger than the QRAT device itself. Highly accurate sensor systems are combined with state-of-the-art processing units to capture and store a wide range of physical data to be used in predictive maintenance and other history-based prognostics. Triaxial vibration, physical shock, temperature, humidity, and voltage transient data are processed and recorded in real time by a 0.9 X 3 X 4 inch Sensor and Electronics Package and transferred to a host PC for post collection display and analysis.

14. SUBJECT TERMS
Time Stress Measurement Device (TSMD); sensors, environmental data, digital environmental recorder

15. NUMBER OF PAGES
88

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Table of Contents

List of Figures

List of Figures (concluded)

List of Tables

Section 1
Executive Summary

The Avionics/Electronic Quick Reliability Assessment Tool (QRAT) program was performed by Honeywell Technology Center in Minneapolis, Minnesota, and funded by Rome Laboratory. The Quick Reliability Assessment Tool is a configurable data acquisition device designed to collect, process, and store environmental data for military and commercial electronic systems. Highly accurate sensor systems are combined with state-of-the-art processing units to capture and store a wide range of physical data to be used in predictive maintenance and other history-based prognostics. Tri-axial vibration, physical shock, temperature, humidity, and voltage transient data are processed and recorded in real time by the 3-in. × 4-in. × 0.9-in. Sensor and Electronics Package and transferred to a host PC for post-collection display and analysis.

The QRAT package includes all of the essential hardware items for a complete data acquisition tool. The internal and external sensors, battery pack, debrief link hardware, and portable host PC all fit in an aluminum transport case. The complete system software includes the complex data acquisition and processing routines in the Sensor and Electronics Package, host-interface and file-handling routines running in a DOS shell on the host PC, and the window-based third-party data spreadsheet/display program, DaDisp. A photo of the QRAT package is shown in Figure 2-1.

This report contains a technical discussion of the system elements delivered under this contract. Included is a discussion on the mechanical, electronic, and software design. A discussion on the testing of the QRAT is presented. A video version of the QRAT testing is also available. The referenced documents are the User Manual, Firmware Support Manual, and Electronics Schematics.

The hardware developed is described by the original statement of work as an "Exploratory Development Model (EDM)" of the Avionics/Electronic Quick Reliability Assessment Tool. To be consistent with that original SOW terminology, the device is referred to as the EDM. The term EDM is used to describe an item used for experimentation or tests to investigate or evaluate the feasibility or practicality of a concept, device, or circuits or system in breadboard or rough experiment form, without regard for the eventual overall fit or final form.

Section 2
Introduction

The Quick Reliability Assessment Tool (QRAT) is a configurable data acquisition device designed to collect, process, and store environmental data for military and commercial electronic systems. Highly accurate sensor systems are combined with state-of-the-art processing units to capture and store a wide range of physical data to be used in predictive maintenance and other history-based prognostics. Internal or remote tri-axial vibration and physical shock, internal ambient and surface (case) temperature, remote temperature, remote humidity, and voltage transient data are processed and recorded in real time by the 3-in. $\times$ 4-in. $\times$ 0.9-in. Exploratory Development Model (EDM) Sensor and Electronics Package and transferred to a host PC for post-collection display and analysis.

Background and Objectives

The Quick Reliability Assessment Tool was needed to fill the technical void for a stand-alone, compact, easily and quickly attached portable system for quick reaction measurement and recording of environmental and operating stresses in Air Force avionics systems. Previous collection means were bulky, difficult to implement, and usually required a dedicated host system during the data collection period. An advanced version of the micro Time Stress Measurement Device (TSMD) was seen as a very good solution to this problem. Micro TSMDs are integrated sensor devices in micro-electronics packages which measure and digitally record selected environmental and operational stress conditions. The recorded data can be subsequently retrieved for review and analysis. Rome Laboratory has been a forerunner in micro TSMD development. The TSMD payoff is a record of environmental and operational stress conditions which can be used for several purposes to enhance reliability, maintainability, and readiness of Air Force systems. Examples of potential data usage are: parameters for definition of environmental design envelopes, loads and boundary conditions for input into thermal and mechanical stress simulations (such as finite element analysis), and acquisition of data for characterizing failures. Micro TSMDs are planned for integration, both into new system designs and into retrofits to existing systems, and could provide this type of information for those systems. There are, however, many remaining systems in the inventory which will not have TSMD capabilities built in, and for these systems, the Quick Reliability Assessment Tool developed under this effort provides very crucial information in a very timely manner without disturbing the operational mission.

Accomplishments

Three Exploratory Development Models of an Avionics/Electronics Quick Reliability Assessment Tool were designed, fabricated, and tested. The EDM is a stand-alone system consisting of the EDM sensor and electronics package, the EDM battery, the remote vibration/shock sensor, the remote humidity sensor, and the remote temperature sensor. The EDM was based on an architecture similar to that used in micro Time Stress Measurement Devices (TSMDs) with enhancements necessary to meet the continuous vibration measurement requirement. Most devices that monitor vibration by performing a fast fourier transforms do so with time gaps between the sample sets. The QRAT EDM continuously samples and performs fast fourier transforms with a digital signal processor. This is to ensure that no data is lost. Functional performance testing in a laboratory was conducted on the EDMs to verify and demonstrate accurate parameter measurement and recording capabilities, and to verify physical integrity under these conditions.

The three delivered Quick Reliability Assessment Tool Sensor and Electronics Packages are shown in Figure 2-2. The Sensor and Electronics Package is 3 in. x 4 in. x 0.9 in. This size is small enough to allow it to be placed with existing avionics.

A block diagram architecture of the Quick Reliability Assessment Tool is shown in Figure 2-3.

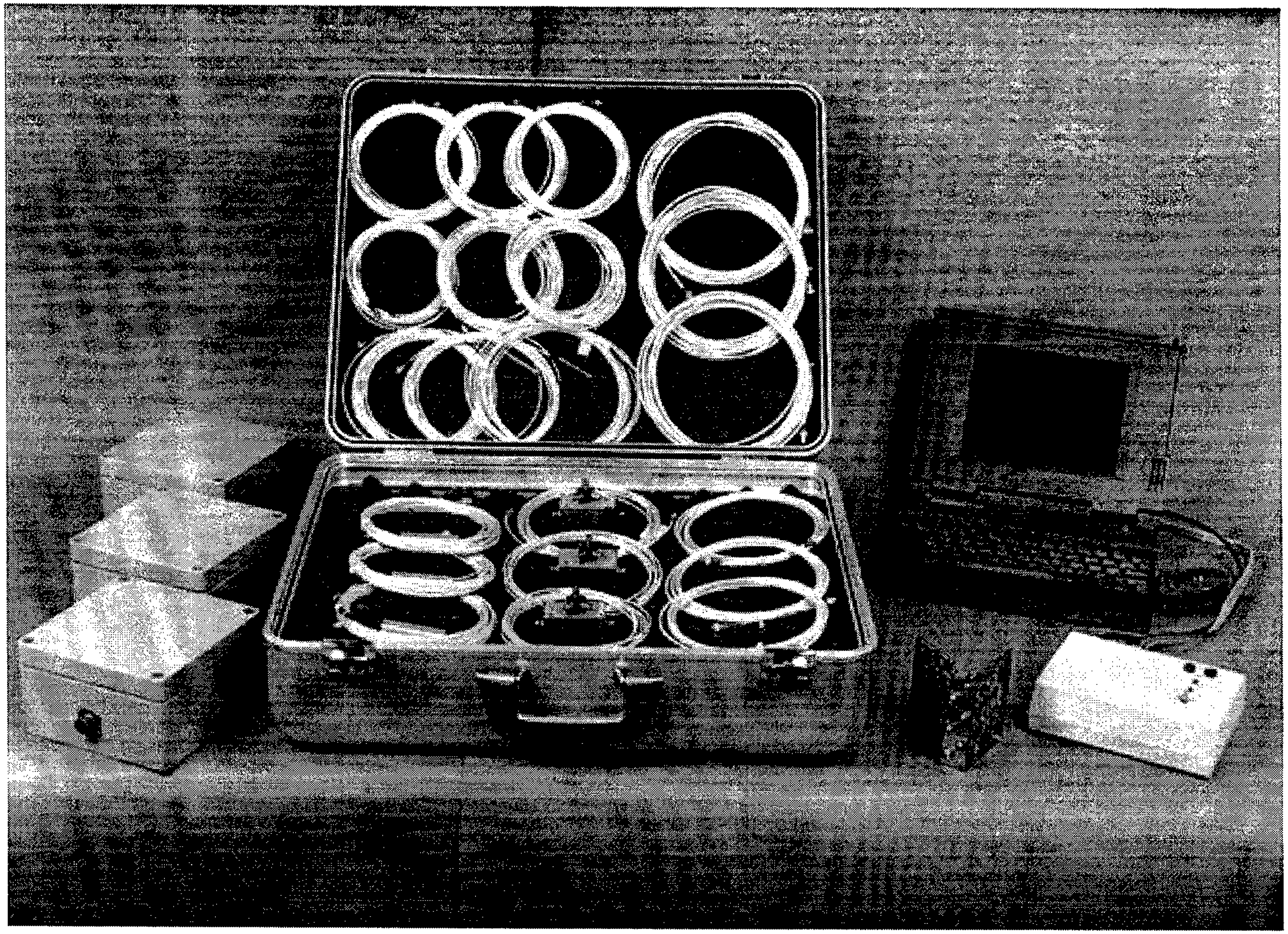


Figure 2-1. Photo of the Quick Reliability Assessment Tool suitcase. The battery boxes are shown on the left; the cable assemblies and external sensors are shown in the suitcase; the debrief computer and the Special-Purpose Interface Adaptor (SPIA) are shown on the right. Also shown, next to the SPIA, is the Sensor and Electronics package with its cover removed.

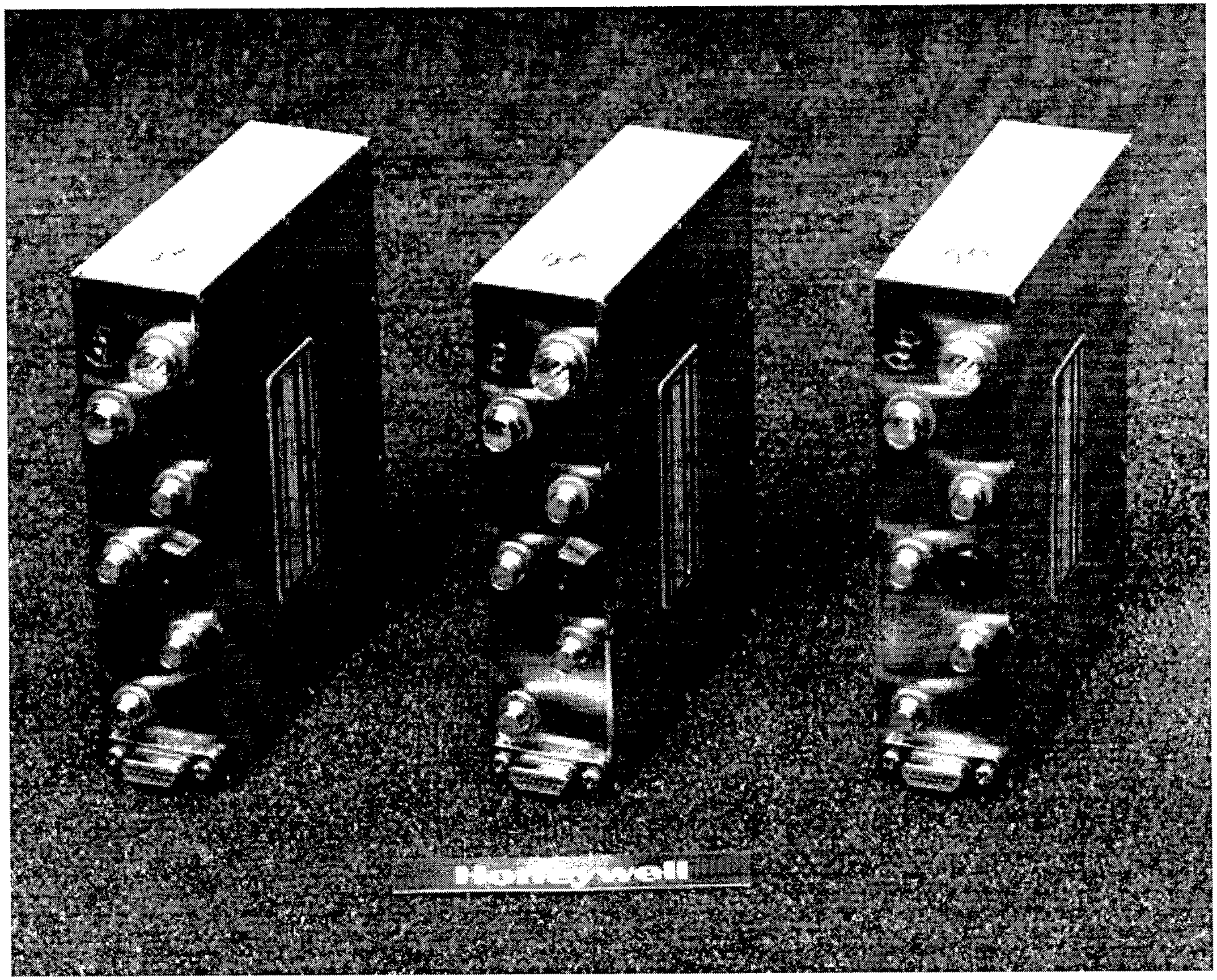


Figure 2-2. Photo of Three Quick Reliability Assessment Tool Sensor and Electronics Packages Delivered on the Program

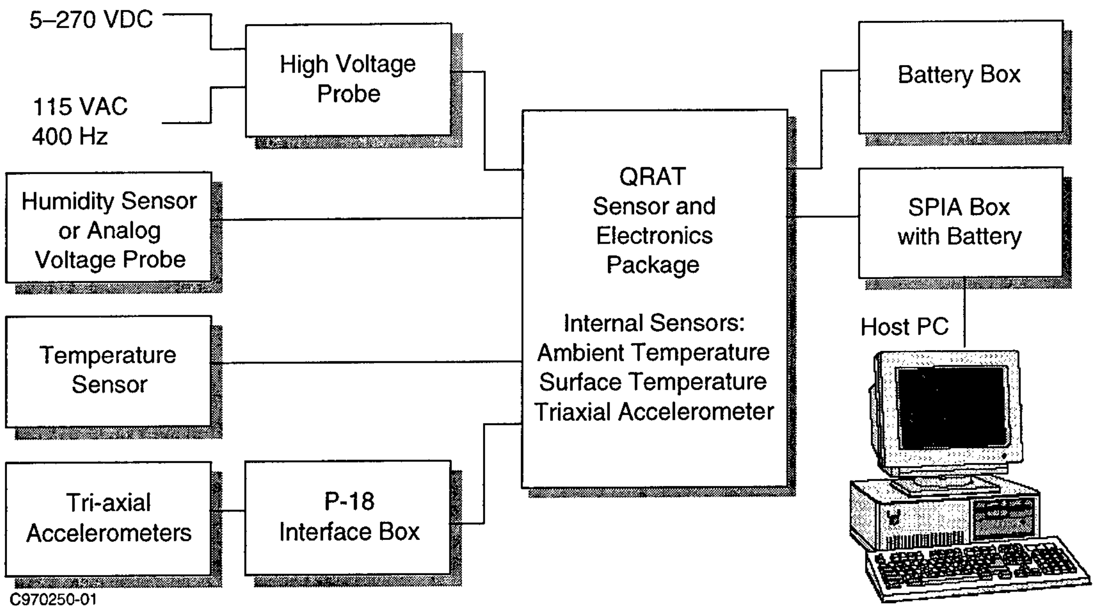


Figure 2-3. Block Diagram of the EDM System.

The EDM Sensor and Electronics package provides the majority of the EDM functions, including:

- Internal and Remote Tri-axial Vibration Sensors
- Internal and Remote Shock Sensors
- Remote Temperature Sensor
- Internal Ambient and Surface Temperature Sensors
- AC or DC Line Voltage Transient Peak Sensing
- Remote Humidity Sensor
- Analog and Digital Signal Processing and Conditioning
- Data Compression
- Long-term Non-Volatile Data Storage
- Real-Time Keeping
- Built-in-Testing (BIT)

Other data analysis functions are provided using the commercial display software package DaDisp running on a host computer. Figure 2-4 is a photograph of the EDM Sensor and Electronics Package.

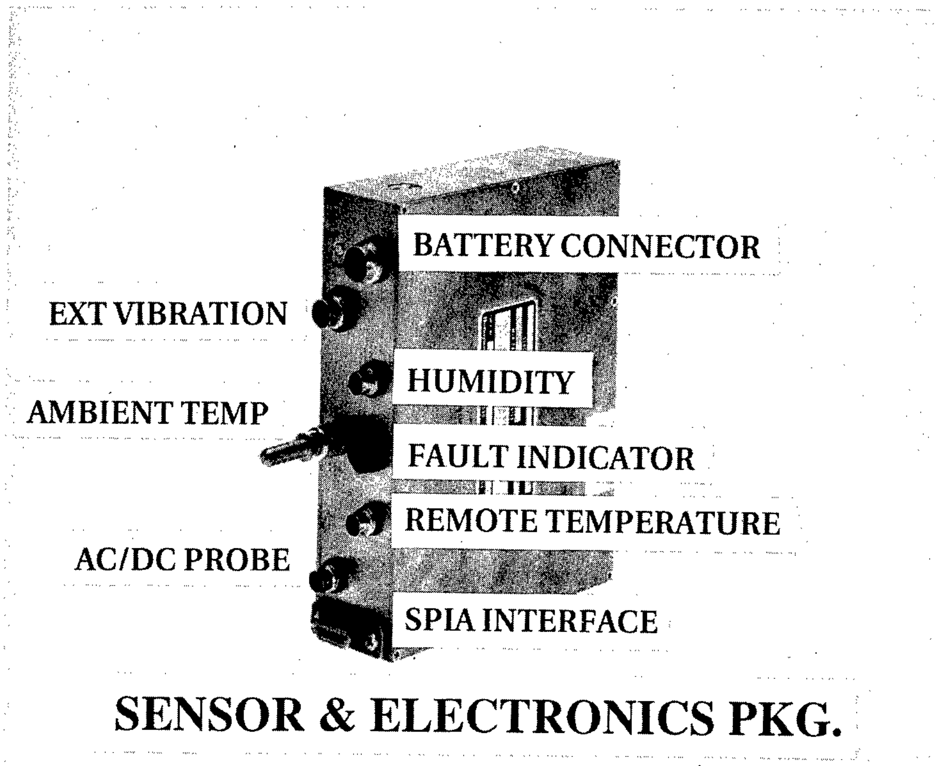


Figure 2-4. Photograph of EDM Sensor and Electronics Package

Internally, the EDM Sensor and Electronics Package contains sensors for measuring vibration, shock, case (surface) temperature, ambient temperature, and voltage transients.

The EDM has remote sensors for measuring aircraft power, vibration/shock, humidity, and temperature. These sensors are packaged to reduce the effects of EMI and to be easily mounted on a variety of surfaces.

Section 3
System Hardware

The Honeywell Quick Reliability Assessment Tool (QRAT) includes several major components. The Exploratory Development Model (EDM) Sensor and Electronics Package is connected directly to the sensors and collects, processes, and stores data in real time. Data is collected from the independent sensor sources listed in Table 3-1.

Table 3-1. QRAT Sensor Systems

QRAT Sensor Systems
Remote Tri-axial Accelerometers
EDM-Internal Tri-axial Accelerometers
Remote Humidity/Analog Voltage Sensor
Remote Temperature Sensor
EDM-Internal Surface and Ambient Temperature Sensors
Remote High-Voltage AC/DC Transient Probe

3.1 System Processor

The Quick Reliability Assessment Tool employs a Texas Instruments TMS320C50 as the main system control and signal processing unit. This processor was released in 1991. With its unique versatility and real-time performance, a TMS320C50 generation processor offers better, more adaptable approaches to traditional signal processing problems and supports complex applications that often require several operations to be performed simultaneously. Key features of the processor include a 16-bit 28.6-MIPS (million instructions per second) core, 32-bit primary accumulators, a 10-Kbyte high-speed instruction/data cache, 16-bit external address and data buses, JTAG scanning logic (supports in situ emulation), and numerous DSP instruction set enhancements. Advanced CMOS processing technology keeps power consumption at around 250 mW (at full speed in the QRAT). In shutdown mode, the processor maintains RAM and interrupt timer functionality but consumes only 2.5 mW.

3.2 Analog Signal Acquisition Processor

To off-load I/O overhead from the main QRAT processor, two independent data acquisition processors were used to maintain continuous data acquisition activities. The National Semiconductor LM12458 combines eight channels of fully differential self-calibrating (correcting linearity and zero errors) 13-bit (12-bit + sign) analog-to-digital conversion with a sample and hold circuit and basic digital buffering functions. Programmable acquisition times and conversion rates are maintained using internal clock-driven timers. All control registers, RAM, and FIFO-buffered data are accessed directly through an addressable 16-bit high-speed processor port. These data acquisition parts consume less than 25 mW of power when fully active and about 50 μW in sleep mode.

3.3 Battery System

The EDM uses main battery power to perform all functions for a maximum mission period of 30 days of unattended operation with vibration present for 25% of this mission; with vibration present for the entire mission, the system battery will last approximately 10 days. Lithium thionyl batteries were chosen because of their high energy density per unit volume (more than 50% greater than the next best lithium chemistry and two to three times more than a mercury zinc battery) and their ability to deliver power over the full range of the QRAT operating temperature. The main battery is six cells of type 33-127 (size DD) from Battery Engineering Inc. (see Figure 3-1). These lithium cells are 3.67-V open circuit and have a capacity of 28 Ah each. Using a 50% temperature de-rating, the battery system is specified to supply a total of 84 Ah. A linear regulator maintains a 5-V output to the Sensor and Electronics package. Two Battery Engineering Inc. model 25-1-2HT (size CC) lithium batteries are also included in the main battery box and are used to power the accelerometers. See Appendix B, sheet 2.

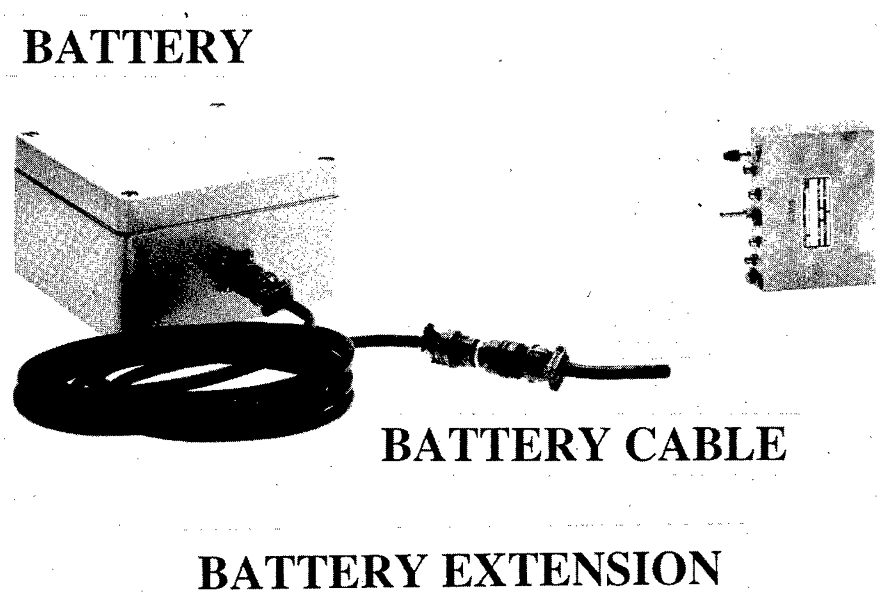


Figure 3-1. QRAT Battery System

For the battery pack, an aluminum watertight EMI shielded enclosure manufactured by Rose Enclosures is used (Dimensions: 8 x 9 x 4 in.) . Their RFI series of off-the-shelf enclosures has been used for the battery package in the "TSMD for B-52 Missile Test Program." The batteries are mounted in the box with brackets. The battery extension cable is 15 feet, and should not be lengthened; the battery cable is 4 feet in length and also should not be lengthened. Use the battery extension cable when the 4 foot battery cable is not long enough to reach the battery box.

Alternative battery packages and power sources are not recommended with the QRAT system. Due to the relative design complexity and varying system voltages, it is recommended that the EDM be powered only by the main battery pack or the SPIA module.

3.4 System Memory

Main system memory is divided into three physical locations: on-chip processor memory (described in Section 3.1), external program memory, and external data memory. Both the external program and external data memory are held in individual parallel connected 1-Mbit (64K x 16 bit) electrically erasable and programmable read-only memory (EEPROM) chips (Model AT28C1024).

The AT28C1024 is a high-performance EEPROM. It is manufactured with Atmel Corporation's advanced nonvolatile CMOS technology, and the device offers access times down to 120 ns with a power dissipation of just 550 mW. In standby, the device current is less than 400 μA. The AT28C1024 is accessed like a static RAM in both the read and write cycle and does not require any external components. It has additional features to ensure high quality and manufacturability. The device uses internal error correction for extended endurance and improved data retention characteristics. An optional software data protection mechanism is available to guard against inadvertent writes. The device also includes an extra 64 words of EEPROM space for device identification or tracking. Data retention of the AT28C1024 is specified at 10 years with an endurance minimum of 10000 cycles.

The procedure for programming the EDM Sensor and Electronics Package is outlined in the QRAT Firmware Manual.

3.5 Temperature Sensing

The QRAT EDM system includes three temperature probes (Analog Devices model AD590). Two of the probes are local to the Sensor and Electronics Package and sense ambient air temperature (in the vicinity of the Sensor and Electronics Package) and surface temperature (of the surface on which the Sensor and Electronics Package is mounted). The ambient air temperature sensor is mounted in a small probe assemble that extends away from the EDM package about one inch. The surface temperature sensor is attached to the interior front wall of the brass Sensor and Electronics Package enclosure. It is located centrally on the wall that contains the connectors. The third sensor is remotely mounted. The two internal sensors are calibrated to measure temperature from –55°C to +95°C, and the external sensor can measure from –55°C to +125°C. The EDM software recognizes and records data from only two of the three sensors on any given mission. Figure 3-2 below shows the connection of the external temperature sensor to the EDM Sensor and Electronics Package. Section 5.2 details the sensor selection and sampling rate options configurable in the EDM software.

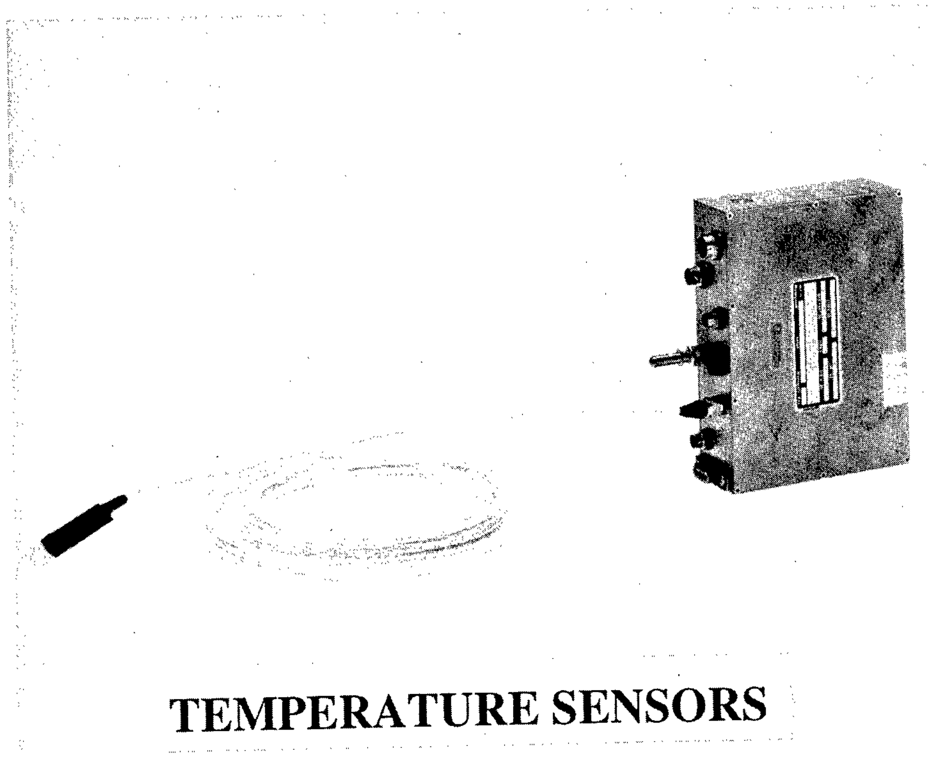


Figure 3-2. Connection of Remote Temperature Sensor to the Sensor and Electronics Package

A close-up of the temperature-sensitive element is show in Figure 3-4. All three of the temperature probes use the AD590 current-type sensor element, which is accurate within 1 degree C. The primary transducer element allows a varying amount of current to pass according to the element temperature. This type of data transfer makes the systems essentially impervious to the effects of voltage drop experienced in long cabling runs (< 100 feet). The temperature transducer passes an output current proportional to absolute temperature (1 μA/K), and a precision 1-KΩ resistor is coupled with op-amp gain to ready the signal for digital conversion. Figure 3-3 below shows a schematic diagram of the temperature sensor interface circuits.

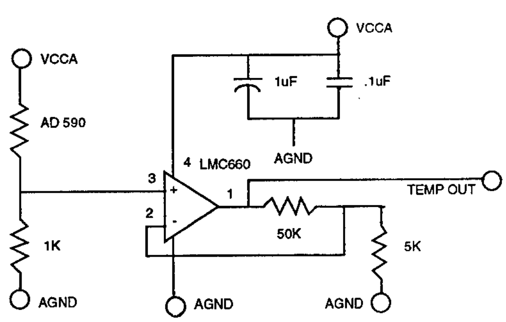


Figure 3-3. Schematic Diagram of the Temperature Sensor Circuits

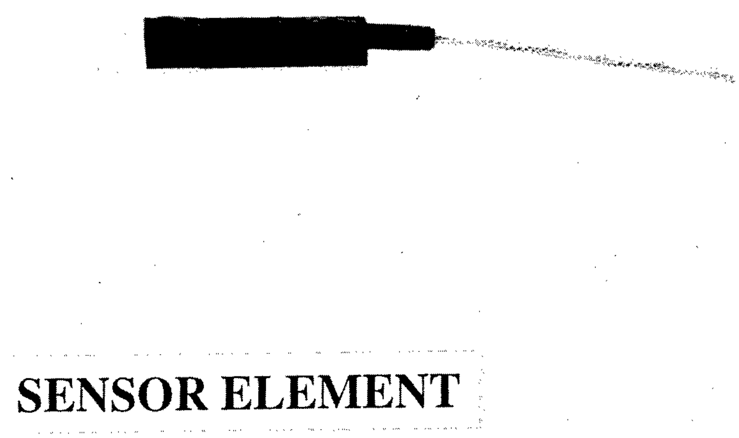


Figure 3-4. Photograph of Potted Temperature Sensor

In the remote sensor, the temperature transducer is mounted and potted on a thin strip of aluminum. The aluminum strip can, in turn, be mounted to any surface under inspection. Short-duration sensor lag is medium dependent and consistent with the thermal transfer characteristics of a block of aluminum approximately 1.5 x 0.8 x 0.25 inch. At system sampling rates in free air, this lag is likely negligible. Temperature sampling intervals are user selectable from: 1, 5, or 15 seconds; or 1, 5, or 15 minutes; or 1 hour.

3.6 Vibration and Shock Sensing

The QRAT EDM system senses motion on three orthogonal axes using either internal or external accelerometers (External: vibro-meter model 505; Internal: vibro-meter model 501). Software selection of the accelerometers is accomplished using a solid-state analog switch. The external accelerometers receive regulated power and have their active signal decoupled from the power source in an external interface module. The vibro-meter P-18 box, supplied by vibro-meter, performs this task for all three axes of motion. The connection of the external accelerometers is shown in Figure 3-5. The maximum length for the cable connecting the Sensor and Electronics Package to the P-18 box is 25 feet, and the maximum length for the cable connecting the P-18 box to the tri-axial accelerometer is 15 feet.

The external accelerometers consist of three vibro-meter model 501 piezoelectric elements mounted orthogonally on a threaded block (Figure 3-6). The reduced size and weight of the block facilitate mounting in many locations. Clear labeling on the block indicates the axes.

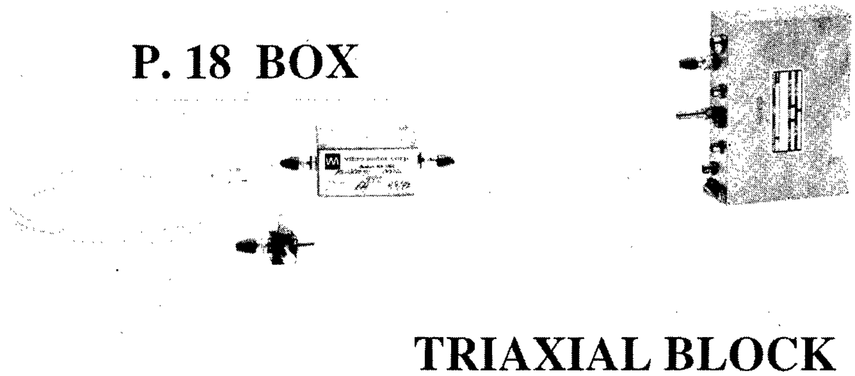


Figure 3-5. Connection of External Accelerometers via P-18 Box

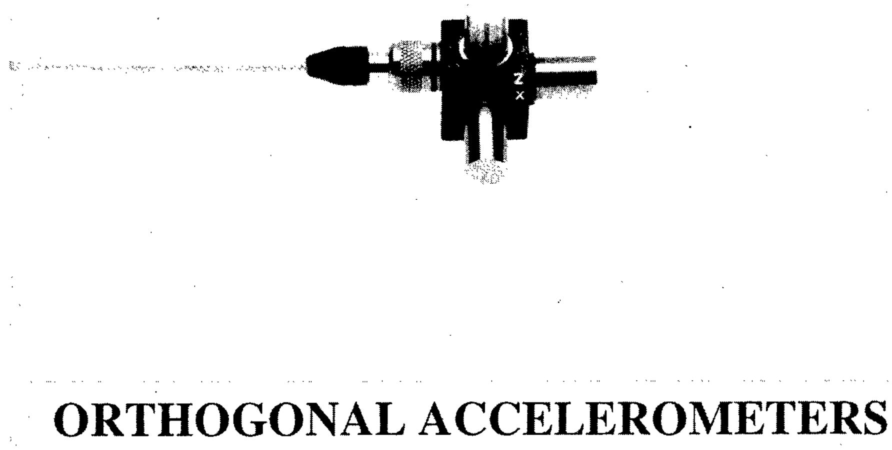


Figure 3-6. Photograph of EDM Remote Accelerometers

The internal accelerometer uses the same circuit components as the P-18 box, but these devices have been placed on the analog printed circuit board inside the Sensor and Electronics Package. As stated above, a solid-state switch controls the selection (for all three axes of vibration) between the internal and external signal sources. Circuitry connected after the selection switch performs two basic functions on each of the three incoming channels (axes): signal conditioning and rectified peak detection. The signal-conditioning portion of the circuit consists of amplification and filtering in preparation for high-speed sampling. Precision gain circuitry sets signal levels to offer minimum distortion up to three G RMS. The rectified peak detectors are used to capture calibrated shock data up to 100 G. Figure 3-7 shows the circuit schematic for one of the input channels.

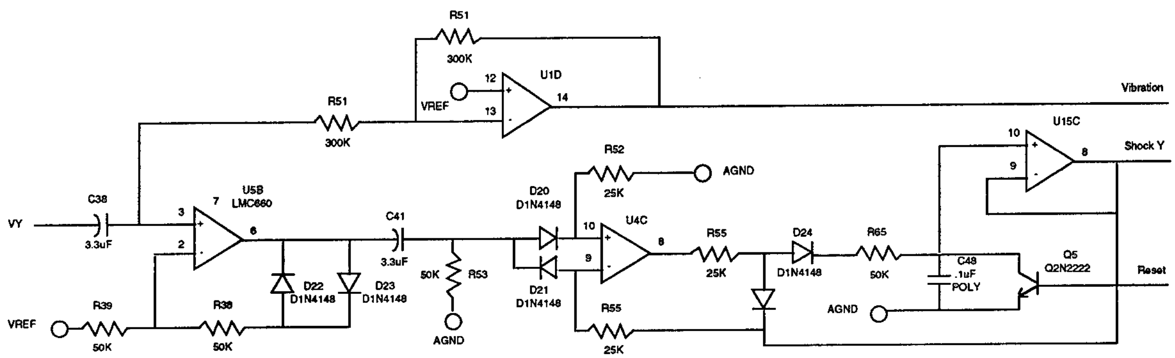


Figure 3-7. Schematic of Vibration Processing Circuitry (single channel)

Filtering of the vibration signal is accomplished using a fourth-order low-pass continuous analog filter. The signal is buffered after the filter and fed to the sampling converter system. Each of the three vibration signals is filtered by a fourth order Chebyshev filter with a corner frequency 2.500 KHz and a lower threshold stopband frequency of 3.2 KHz. Passband ripple is limited to less than 0.75 dB. The data is sampled at 6400 Hz and processed continuously in real time. Figures 3-8 and 3-9 below show gain and phase plots of the filters.

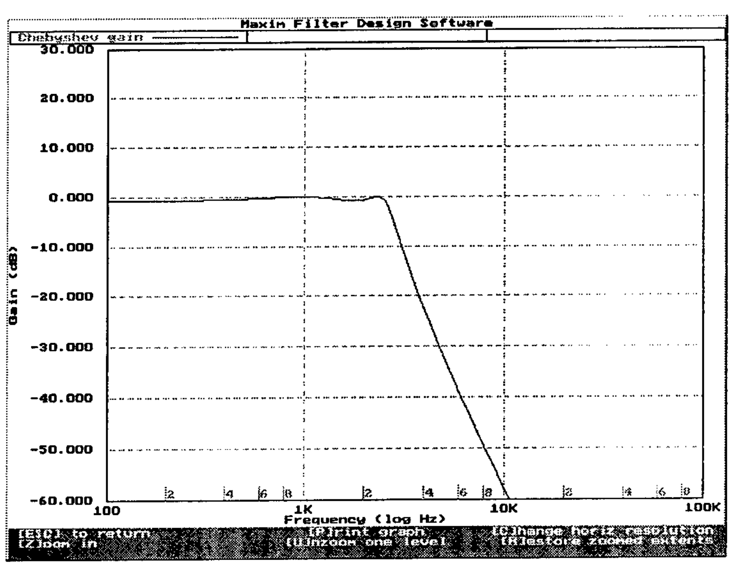


Figure 3-8. Gain Response of Vibration Alias Filter

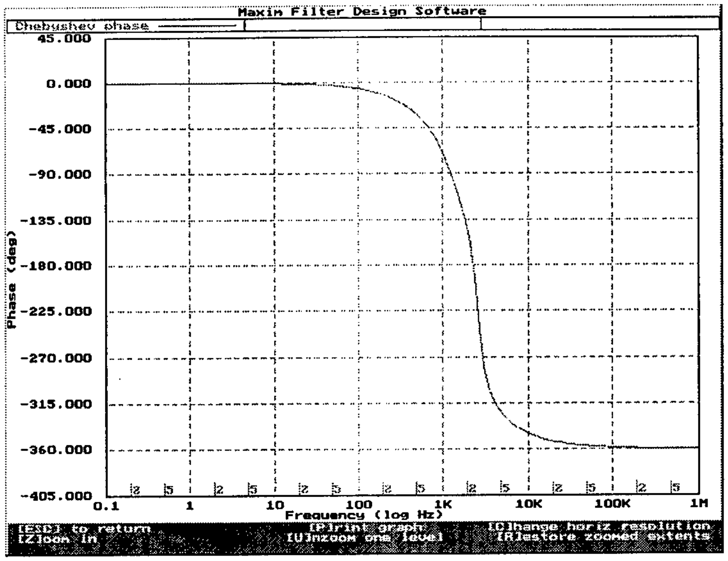


Figure 3-9. Phase Response of Vibration Alias Filter

3.7 AC/DC Probe Line Voltage Sensing

The QRAT system includes an external high-voltage probe that connects directly to either the aircraft AC power system or a DC power source. The high-voltage probe determines whether or not power is present on either the AC or DC sensed line and quantifies the magnitude of any voltage transients on that line. The absolute nominal range of sensitivity for this probe is 270 V DC and 115 V_{RMS} AC, with transient quantification ability above and below these levels to 100 V. Figure 3-10 shows the connection of the high-voltage probe to the Sensor and Electronics Package.

3.7.1 Line Voltage Sensing

The AC/DC line voltage sensor provides signals that indicate the presence of aircraft voltage. These signals are fed into the analog-to-digital converter, and their respective states can be polled by the software routines. Circuitry rectifies and divides the high-voltage signal coming from aircraft power. The AC circuitry indicates signal presence when the voltage reaches 115 V_{RMS} and the DC probe uses thresholds of $5.0 < V_{IN} < 270$ V as an indicator. The functional effects resulting from the detection of either AC or DC aircraft power are discussed below in Section 5.

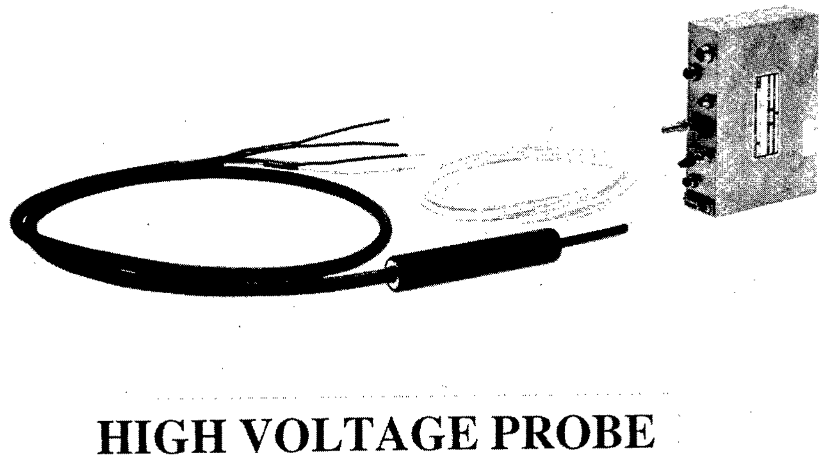


Figure 3-10. AC/DC High-Voltage Probe Connection

3.7.2 Transient Voltage Sensing

In addition to the signal presence detectors of the high-voltage probe, circuitry to detect and quantify voltage transients has been included. This circuit has the capability of detecting voltage transients with a pulse duration down to 1 μs. The external probe circuit provides voltage scaling and filtering to reduce the effects of electromagnetic interference (EMI) before sending the signal into the Sensor and Electronics Package. Circuitry inside the package filters out the nominal AC or DC signal and performs high-speed peak and trough detection to determine the magnitude of superimposed transients. Figure 3-11 shows the circuit schematic of the high-speed circuitry used in the Sensor and Electronics Package to perform this function.

The outputs of the respective peak and trough detectors are fed into the A to D conversion system where they can be read by the main system processor.

3.8 Humidity Sensor

The QRAT system includes a remotely mounted humidity sensor (HY-CAL model IH-3602). The sensor's range includes the full relative humidity spectrum from 0% to 100%. The sensor is powered from the Sensor and Electronics package, and the signal is low-pass filtered before continuing on to the A to D conversion system. Figure 3-12 shows the connection of the humidity sensor to the Sensor and electronics package.

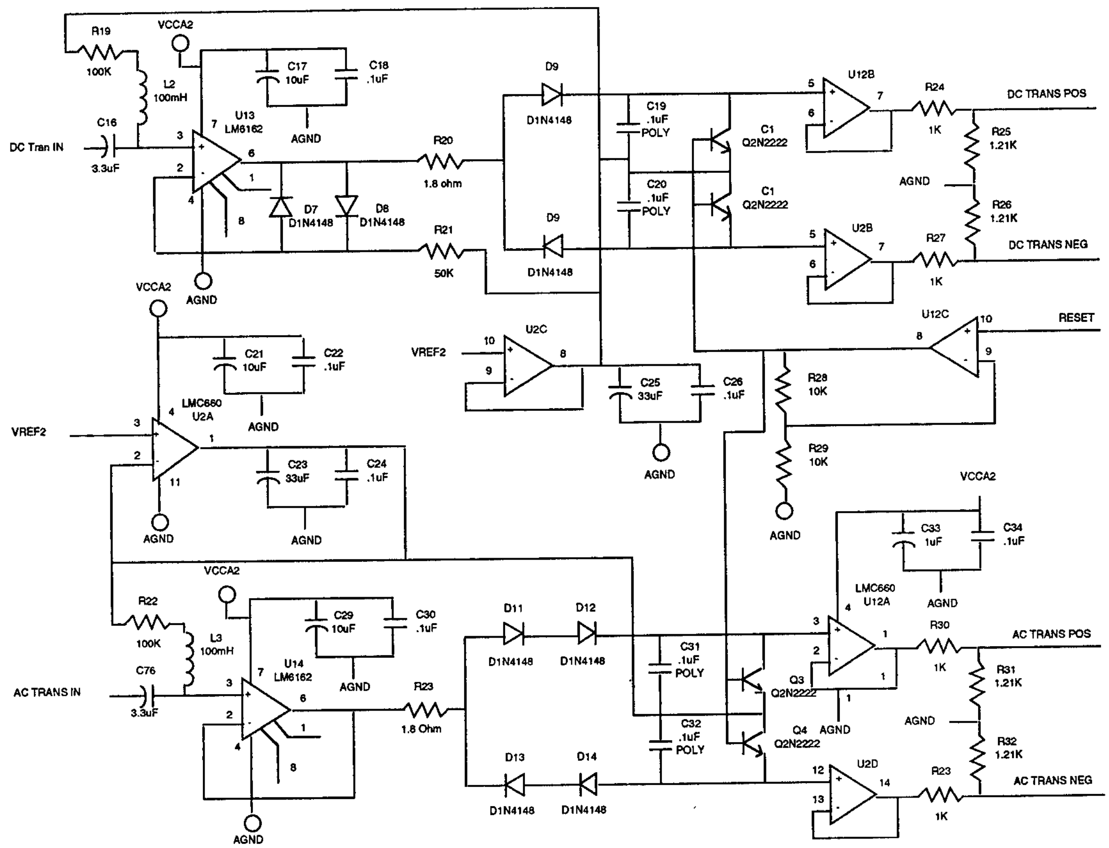


Figure 3-11. Schematic of Transient Detection Circuitry

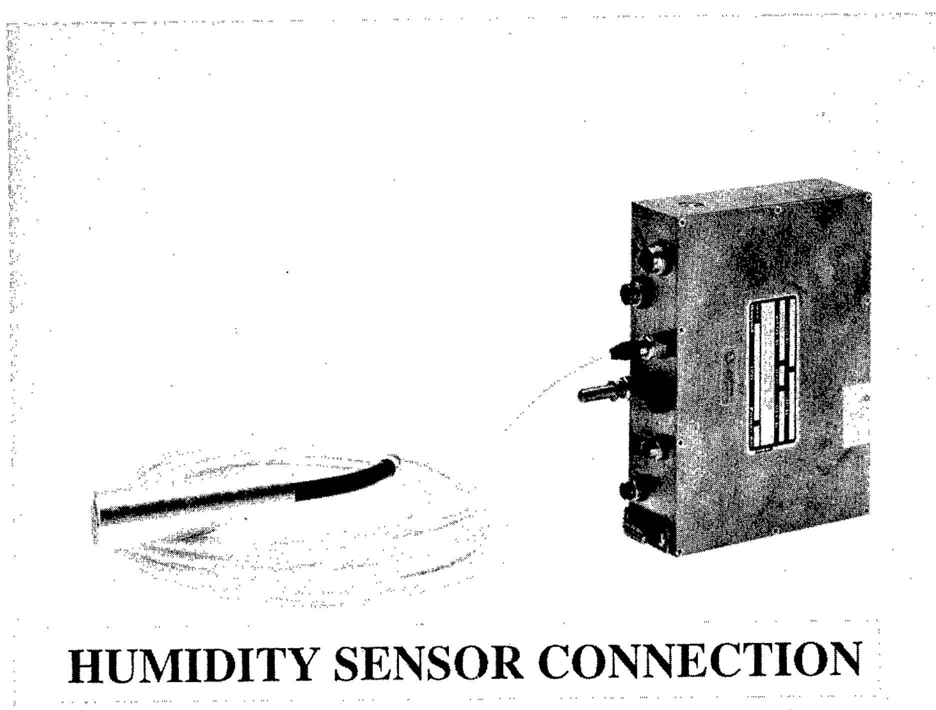


Figure 3-12. Humidity Sensor Connection

The element itself is protected by a thick screen that can be washed in water should blockage develop. The transducer is mounted in a cylindrical sleeve suitable for mounting in a variety of applications. Figure 3-13 shows a close-up view of the remote humidity sensor with the screen of the active sensor element.

SENSOR ELEMENT

Figure 3-13. Humidity Sensor Active Elements

3.9 Analog Input Port

The remote humidity sensor connection port can also serve as a general-purpose buffered input port in applications where monitoring of some external signal is necessary. For example, the on/off state of some special function peripheral that is mounted in an area under environmental inspection. The pin used to provide power to the humidity sensor can also be used as a reference voltage for external circuitry used to drive the analog input port. Care must be taken not to exceed the input and load specifications outlined in the QRAT Users Manual.

A connecting cable that attaches to the three-pin Microtech socket on the EDM module has been included with the QRAT. The wire connections for this port are listed in Table 3-2 below.

Table 3-2. Humidity/Analog Voltage Port Wire Connections

Wire Color	Connection
Red	+5 V power
Black	Signal (0 to 4.5 V)
White	Ground

The input to this port is buffered by a high impedance op-amp (> 1 M Ω). Care should be exercised to ensure that the voltage ratings of $0\ V < V_{IN} < 4.5\ V$ are not exceeded—op-amp destruction may result if adherence to this specification is not maintained.

Section 4
Sensor and Electronics Package Mechanical Design

The package size for the Quick Reliability Assessment Tool program was a major technical challenge. No other data logging system achieves the same level of system performance versus size as the Quick Reliability Assessment Tool Sensor and Electronics Package. It contains the sensors, interface electronics, digital signal processor (DSP), and data memory to assess an avionics environment. This is all done in a package that is 10.8 in^3.

The Sensor and Electronics Package has a three-axis accelerometer and temperature sensing built into it. The Sensor and Electronics Package can be placed within the avionics as a sensor. This can make installation quick in some cases. The same temperature and three-axis accelerometer sensors can be located remotely from the Sensor and Electronics Package. This can be used in cases were the Sensor and Electronics Package cannot fit in an area that needs to be monitored. The remote sensors can also be used in cases were the area is inaccessible for debriefing the Quick Reliability Assessment Tool Sensor and Electronics Package.

The connectors are all conveniently located on one edge of the Sensor and Electronics Package. This allows the module to be inserted into a small space between avionics and still be able to make connections. Figure 4-1 shows the connectors. There are seven connectors and a fault ball indicator. The fault ball is a mechanical display that turns from black to white when indicating a fault.

The internal assembly of the Quick Reliability Assessment Tool Sensor and Electronics Package is shown in Figure 4-2. To give the package mechanical strength, the edges of the box are machined out of one piece. This creates a frame to which the connectors and boards can be mounted. The top and bottom covers mount to the frame piece with screws. Two printed circuit boards contain the electronics of the Sensor and Electronics Package. They are mounted to the frame with screws on an edge that is machined into the inside of the frame. The integrated circuit packages and larger passive components are mounted on the side facing inward on the two boards. The outward facing sides of the boards have the lower profile surface-mount components. They are the resistors, capacitors, and signal diodes. The external connections and connections from the board are along the front edge. The wiring from board to board and to the connectors is all done with discrete wires. This can be seen in Figure 4-3. In a production version of this design, it would be straightforward to replace the wires with a flexible circuit assembly. Having the interconnect along the same edge allows the boards to be folded out like the pages of a book. The ability to have easy access to the board makes electrical checkout of the hardware more efficient. To probe on either printed circuit board, the cover can be removed and the board pulled out.

In Figure 4-2, the location of the three internal accelerometers can be seen in the lower right corner of the connector edge. Only one of the accelerometers is visible from this angle. These are vibro-meter 501 piezoelectric accelerometers. They are the same accelerometers used for the three-axis external sensor. In the software setup, the selection is made as to which accelerometers will be processed by the Sensor and Electronics Package. Figure 4-3 shows a second internal view of the main electronics assembly.

Figure 4-4 shows the component side of the Sensor and Electronics Package's two printed circuit cards. The left board has the interface electronics for the sensors (analog board). The right board has the DSP, real-time clock, analog-to-digital converter, and the memory (digital board). The analog board uses dual-in-line integrated circuit (IC) packages and the digital board uses both dual-in-line and surface-mount packages. It would have made board layout much easier if all packages could be surface mount. This was not possible because of the lack of surface-mount analog ICs that meet both the military temperature range and the performance required. The real-time clock on the digital board had a similar problem. The only real-time clock that met the military temperature range was available in a dual-in-line package. Figure 4-5 shows the opposite side of the Sensor and Electronics Package's two printed circuit cards. This side has capacitors, resistors, and signal diodes.

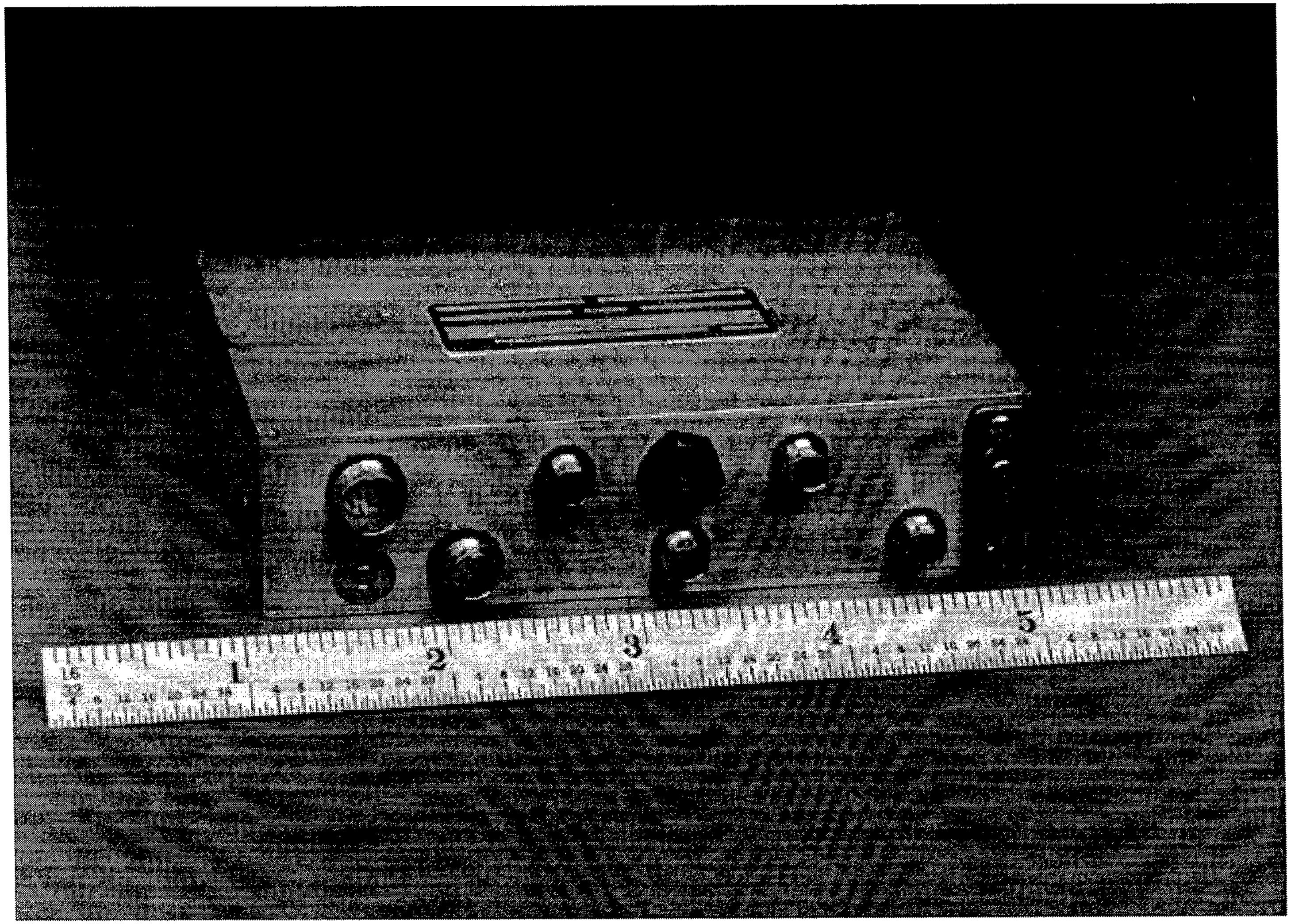


Figure 4-1. Photo of Quick Reliability Analysis Tool Sensor and Electronics Package Showing the External Connections.

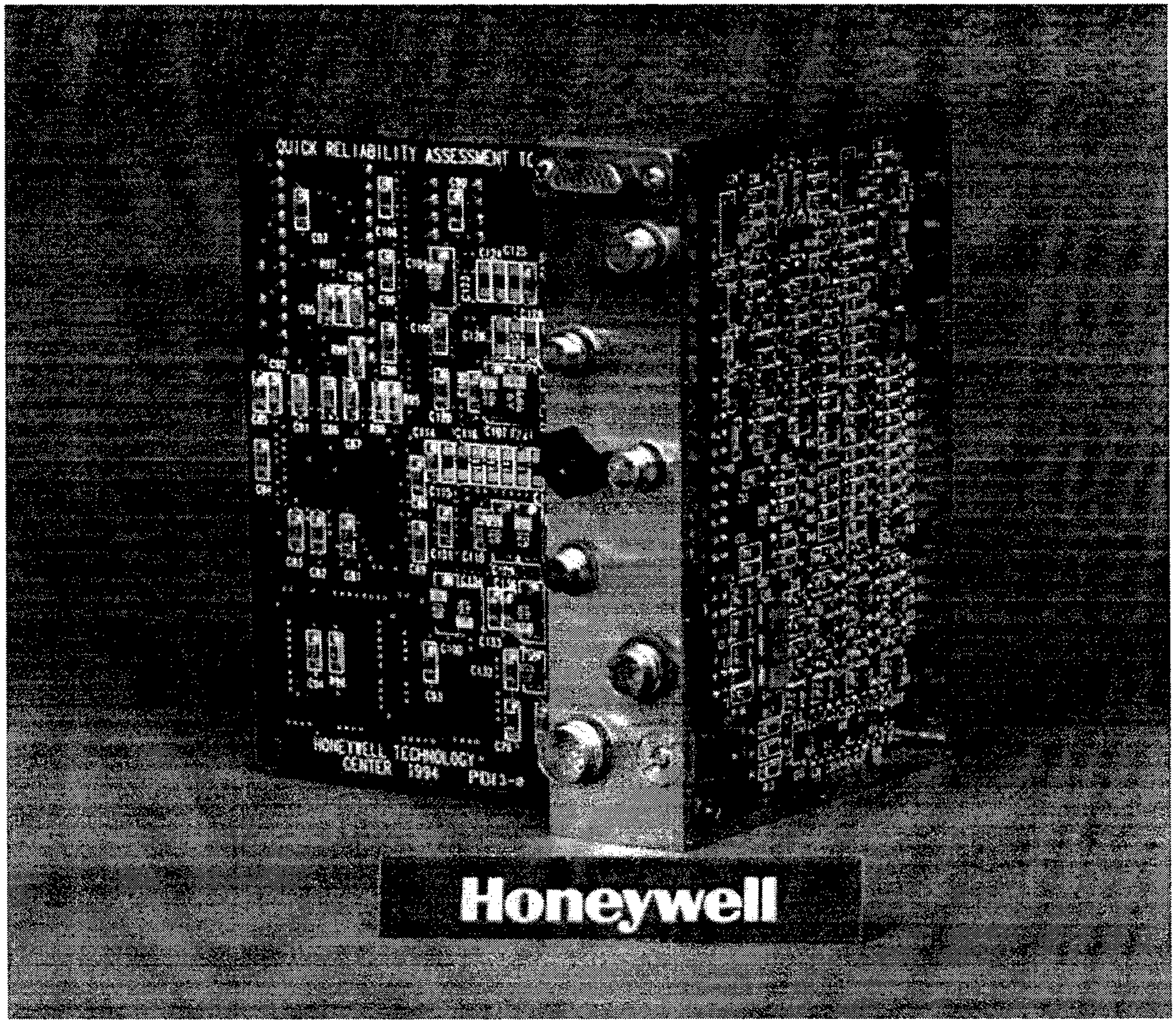


Figure 4-2. Photo of Quick Reliability Analysis Tool Sensor and Electronics Package showing how the two printed circuit boards fit into the Sensor and Electronics Package. One of the three internal accelerometers can be seen in the lower right corner of the front connector face.

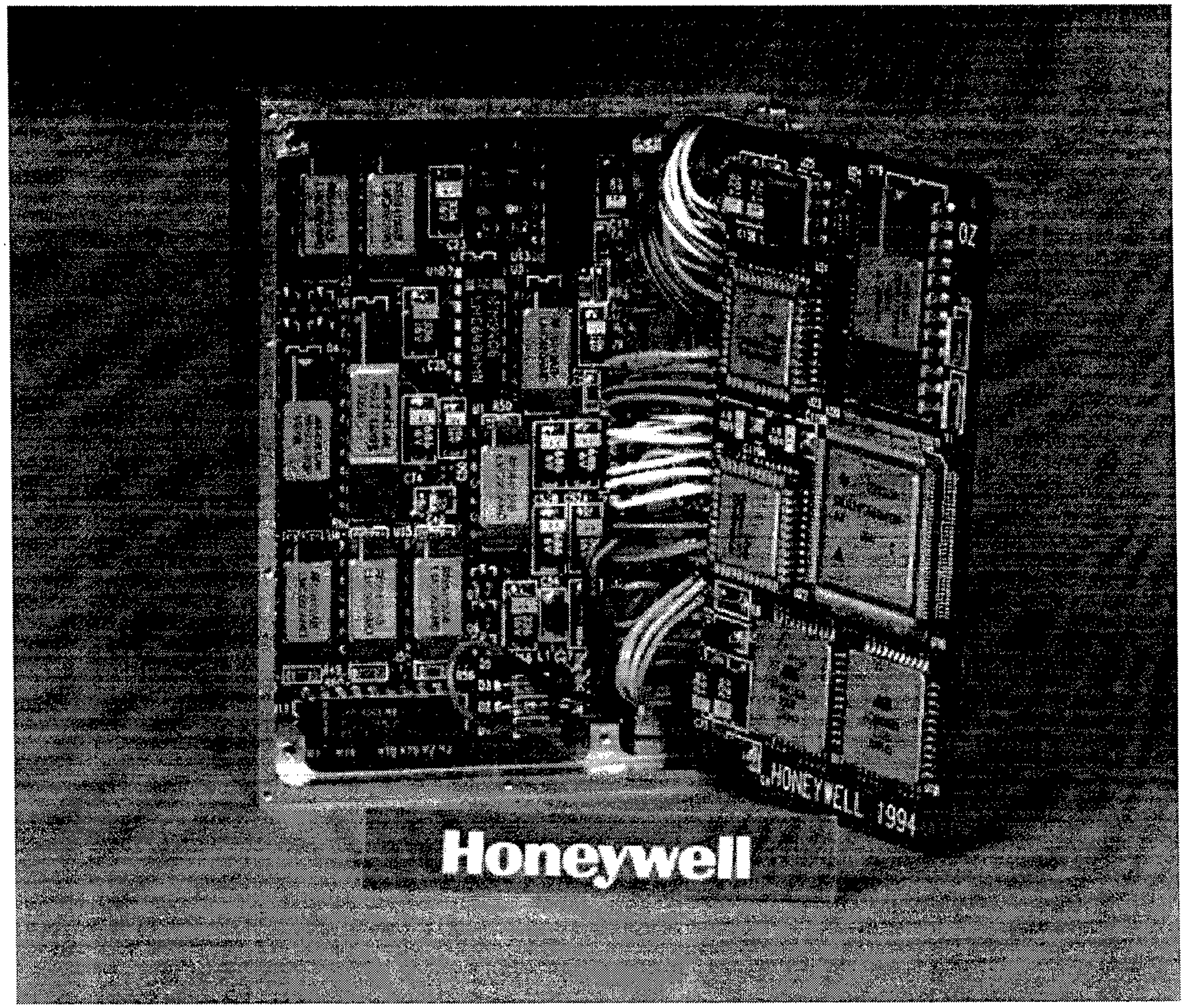


Figure 4-3. Photo of the Quick Reliability Assessment Tool Sensor and Electronics Package showing how the two printed circuit boards fit into the Sensor and Electronics Package. The left board has the interface electronics for the sensors. The right board has the DSP, real-time clock, analog-to-digital converter, and the memory.

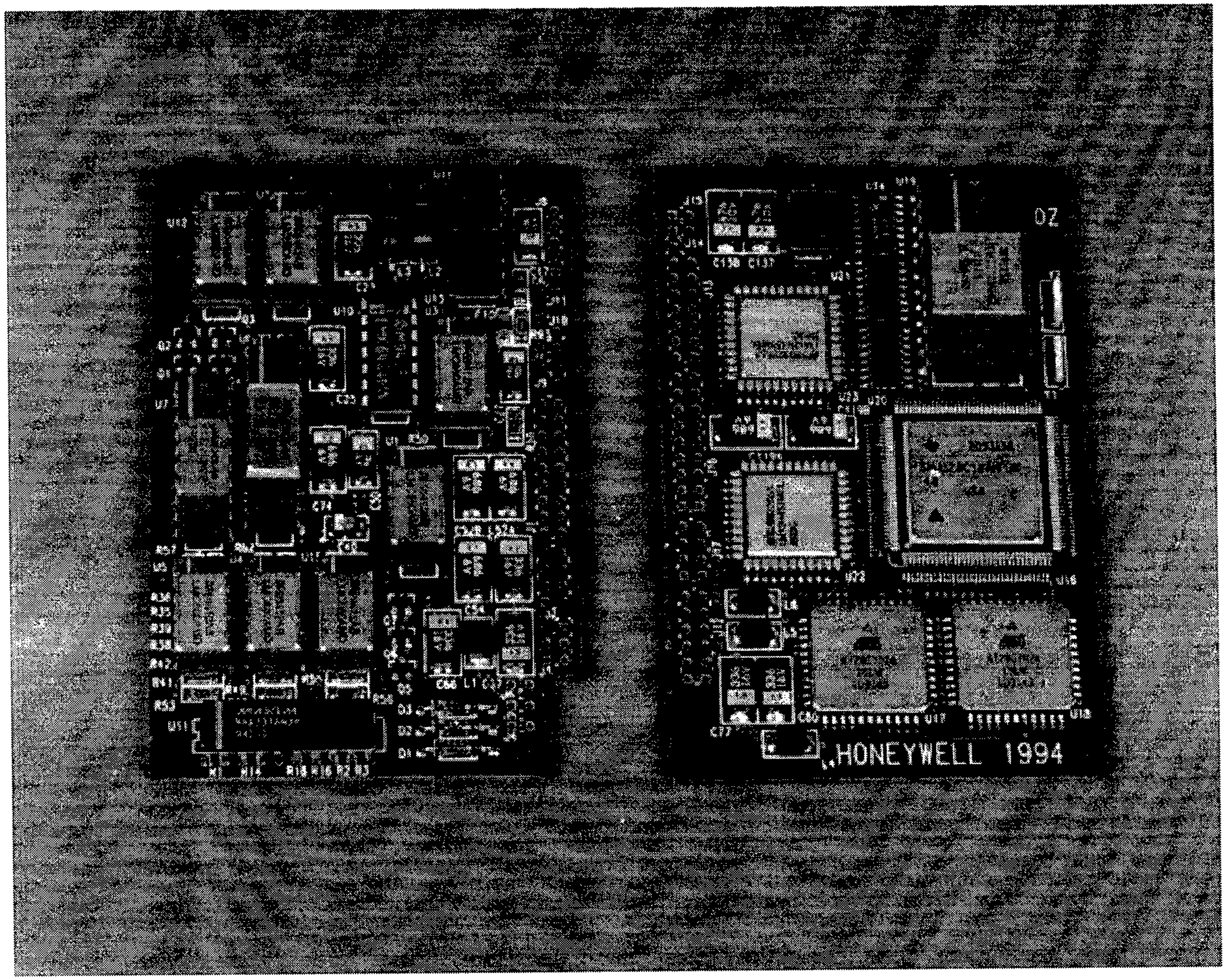


Figure 4-4. Photo of the Quick Reliability Assessment Tool Sensor and Electronics Package's printed circuit boards. The left board has the interface electronics for the sensors. The right board has the DSP, real-time clock, analog-to-digital converter, and the memory.

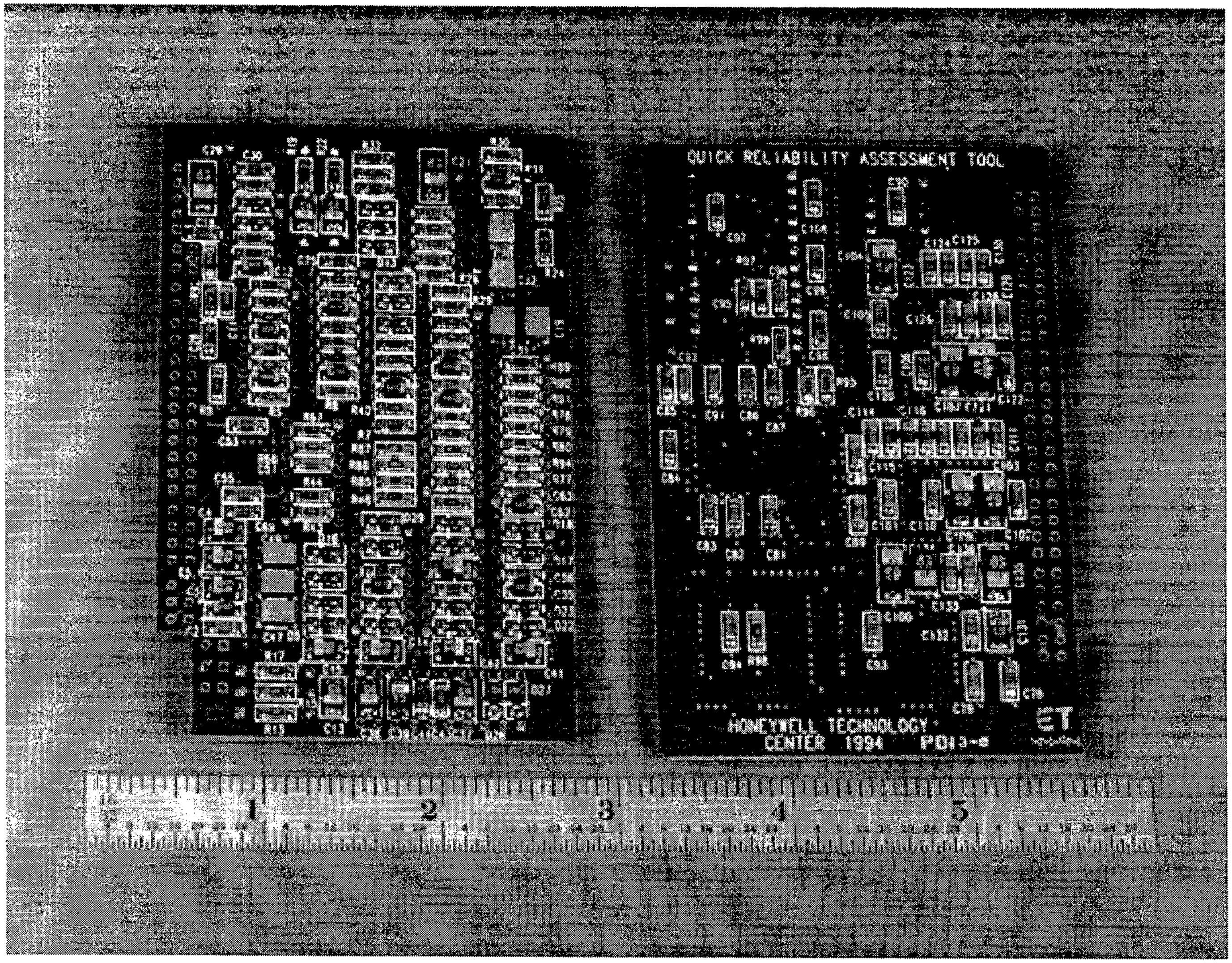


Figure 4-5. Photo of the opposite side of the Quick Reliability Assessment Tool Sensor and Electronics Package's printed circuit boards. The interface electronics board is on the left. The DSP board is on the right.

Section 5
Theory of Operation

The Quick Reliability Assessment Tool (QRAT) is a configurable data acquisition device designed to collect, process, and store environmental data for military and commercial electronic systems. Highly accurate sensor systems are combined with state-of-the-art processing units to capture and store a wide range of physical data to be used in predictive maintenance and other history-based prognostics. Tri-axial vibration, physical shock, temperature, humidity, and voltage transient data are processed and recorded in real-time by the 3 x 4 x 0.9 inch Exploratory Development Model (EDM) module, and transferred to a host PC for post-collection display and analysis.

The QRAT package includes all of the essential hardware items for a complete data acquisition tool. The internal and external sensors, battery pack, debrief link hardware, and portable host PC all fit in a ruggedized aluminum transport case. The complete system software includes the complex data acquisition and processing routines in the EDM module, host-interface and file handling routines running in a DOS shell on the host PC, and the window-based third party data spreadsheet/display program *DaDisp*.

5.1 System Configurations

There are three basic system configurations for the Quick Reliability Assessment Tool: the Sensor/Data Acquisition System, Debrief/Configuration System, and the Firmware/Programming System. The Sensor/Data Acquisition System is the configuration where the actual collection of data takes place. The Debrief/Configuration system is used where data collection parameters and collected data are transferred between the host computer and the EDM Module. And the third hardware configuration, the Firmware/Programming system, is where the EDM Module is connected to the JTAG processor emulation system and EDM Module software is maintained.

5.1.1 Sensor/Data Acquisition System

The Table 5-1 lists the hardware components used in the Sensor/Data Acquisition System (data collection) configuration. The remote (external to the EDM Module package) sensors listed in the table are all optional in this configuration. The collection of data from these sensors is either software selectable, or automatically disabled when no stimuli are present. The software operation and configuration of these sensors is explained in section 5-2.

In this mode, it is assumed that the EDM module is mounted in the field and uses the battery pack for main power. It is possible, however, to power the system in this configuration using the Special Purpose Interface Adapter (SPIA) and an external power supply. This contingency was designed for to allow full lab-testing of the EDM module and sensor systems without compromising the lifetime of the lithium batteries. The SPIA can only provide power to the sensor systems of the EDM module when an **external** voltage supply is used (the internal batteries of the SPIA do not generate the upper voltages used for sensor biasing, they are intended to power the debrief components only).

Table 5-1. Hardware Components of the Sensor/Data Acquisition System

Sensor System Hardware Components
EDM Module (sensor and electronics package).
Remote Tri-axial Accelerometer Package.
Remote Accelerometer Interface Module (P-18 Box).
Battery Pack.
Remote Humidity/Analog Voltage Sensor.
Remote Temperature Sensor.
Remote High-Voltage AC/DC Interface Probe.

5.1.2 Debrief/Configuration System

The EDM module is configured for data collection and debriefed using the same hardware system. The EDM module is connected to the SPIA via the 15 pin D connector on the EDM module and the SPIA is connected to the host computer via the nine pin RS-232 serial cable. The serial port configuration of the host computer is set automatically by the host software package. Power for the EDM in this configuration is supplied from the SPIA box. The SPIA box is, in turn, powered by one of two sources: internal batteries or an external power supply. Both of these sources provide the needed power for configuration and debrief functions (the purpose of the SPIA), but be advised that the internal batteries of the SPIA can not power the sensor systems. Table 5-2 lists the hardware components of the Debrief/Configuration system.

In the Debrief/Configuration setup, the host PC runs the program *deb.exe* to establish and maintain communication with the EDM module. When a link between the EDM module and the PC has been established, the EDM Status line of the main display on the PC will indicate that the EDM is in Standby Mode or Data Collection Mode. All functions are available when the EDM module is in Standby mode, and are described in the Software discussion of Section 5.2 below. To place the system in Standby Mode from Data Collection Mode, select the Stop EDM Data Collection option. All selections are made with the arrow keys, and performed when a <CR> (carriage return) is entered. Main Menu functions appear in highlighted yellow, configuration functions are in highlighted green, and individual settings and messages are displayed in blue.

Table 5-2. Hardware Components of the Debrief and Configuration System

Debrief/Configuration System Hardware Components
EDM Module.
Special Purpose Interface Adapter (SPIA) Box.
PC Computer.
Nine-pin RS-232 Cable.

5.1.3 Firmware/Programming System

The Firmware/Programming System configuration is used to maintain the firmware contained in the EDM Sensor and Electronics Package. This configuration requires the Sensor and Electronics Package to be connected to a Texas Instruments XDS-510 emulator. More detail on this configuration is contained in the Firmware Manual. The emulation system is connected to the EDM module for programming and other firmware operations. The emulation probe of the XDS-510 pod connects to the 14-pin pigtail provided on the special SPIA to EDM connecting cable. The hardware components necessary for this configuration are listed below in Table 5-3.

Table 5-3. Hardware Components of the Firmware/Programming System

Firmware/Programming System Hardware Components
EDM Module.
Special Purpose Interface Adapter (SPIA) Box.
TI XDS-510 Emulator Probe.
TI 320C50 Emulator Card.
PC running TMS C Source Debugger

The TMS 320C50 C Source Debugging system must be properly installed on a PC as explained in the Texas Instruments TMS320C50 Compiler, Emulator, and Linker data books. Additionally, the main system clock for the PC must be connected to a variable frequency source that enables the PC execution speed to be lowered to 1.5 MHz. Note that this slow speed may prove incompatible with many of the DRAMs found in newer PCs. An older (circa 1988) model 80286 was used in this procedure at Honeywell. The need for this reduced clocking scheme arises from the write latency requirement of the EEPROM used to hold program code in the EDM module.

The SPIA is used to provide power to the EDM during the programming procedure. An external power supply must be used with a setting between 12 and 16 V. The power switch on the SPIA is set to external.

The programming procedure for the EDM module is simple; given that the environment is properly set up as explained in the Texas Instruments manuals. Table 5-4 lists the step-by-step instructions for programming the EDM modules. The procedure assumes that the system emulator is installed correctly and that a copy of the object code to be placed in the EDM module is in the emulator directory under the name *qrat.out*. The items listed as "Emulator Command" are commands issued in the text command window of the emulator.

Table 5-4. EDM Module Programming Procedure

EDM Firmware Programming Steps
1. Set PC Clock to full-speed.
2. Connect SPIA to EDM module.
3. Connect Emulation Probe to SPIA cable.
4. Power SPIA.
5. Run *emulate.bat*.
6. Emulator Command: RESET.
7. Set PC clock to 1.5 MHz.
8. Emulator Command: LOAD "*QRAT.OUT*".
9. Emulator Command: QUIT.
10. Turn OFF SPIA and disconnect cables.

The file *qrat.out* is the linked object file of the EDM module software listed in Appendix A of the Firmware Manual. Note that there is a serial number in the program space that corresponds to the hardware serial number of the programmed device. This number is used by the calibration software to access the proper calibration file during data formatting.

5.2 EDM Module Software

The EDM module software controls data acquisition and communication between the host PC and the EDM module. Data acquisition parameters are set by configuring the system in Debrief/Configuration mode and setting the parameters via the host PC. The parameters are downloaded to the EDM module when the device enters Data Collection or Built In Test mode.

The powered EDM module can be in one of three modes: Standby, Built In Test, or Data Collection. These modes are selected from the main menu on the host PC running *deb.exe* while the system is in the Debrief/Configuration setup (see section 5.1.2). The following sections break down the EDM software into five distinct areas: setting/viewing data collection/configuration parameters, data collection procedures, data debrief, Built In Test Mode, and calibration.

The EDM has two main modes of operation: Standby Mode and Data Collection Mode. Standby Mode allows the user to set the data collection parameters, initialize data, upload data to the host PC, enter the built-in test mode, and enter the Data Collection Mode. The Data Collection Mode uses the parameters set during Standby Mode to collect, process, and store environmental data.

A top-level flow diagram for the Standby Mode is shown in Figure 5-1. The Standby Mode of the EDM has four basic functions. The first function is the selection of the data collection parameters. The second function is initializing the data memory to clear any data from previous missions. Built-in test is a third function of the Standby Mode used to determine the condition of the EDM and its sensors. The fourth function is debriefing of environmental data.

The manner in which the environmental data is collected can be controlled by the selection of the EDM parameters. A summary of the data collection parameters is shown in Table 5-5. A review of zero-order data predictors can be found in appendix D, and a review of the fast fourier transform (FFT) can be found in appendix E.

Table 5-5. Data Collection Parameters

Collection Parameter	Domain
Shock Detector Source	Internal or external
Minimum Shock Threshold	$3\ G \le xx \le 100\ G$
Vibration Monitor Source	Internal or External
Vibration Zero-Order Predictor Delta	$4 \times 10^{-3}\ G^2/Hz \le xx \le 200 \times 10^{-3}\ G^2/Hz$
Temperature Sources	Two of: Remote, surface, or ambient
Temperature Sampling Rate (Active Mode)	1, 5, or 15 sec., or 1, 5, or 15 min., or 1 hr
Temperature Sampling Rate (Sleep Mode)	1, 5, or 15 sec.; or 1, 5, or 15 min.; or 1 hr
Temperature Zero-Order Predictor Delta	$0°C \le xx \le 50°C$
Voltage Transient Source, Minimum Level	AC: ±25 V, ±40 V, or ±55 V; or DC: ±25 V, ±40 V, or ±55 V
Humidity (Analog Voltage) Delta	1.5% RH (0.0474 V) _ xx _ 100% RH (3.1584 V)
Initialize Data Memory	Reset or not reset
Time and Date	mm/dd/yy hh:mm:ss

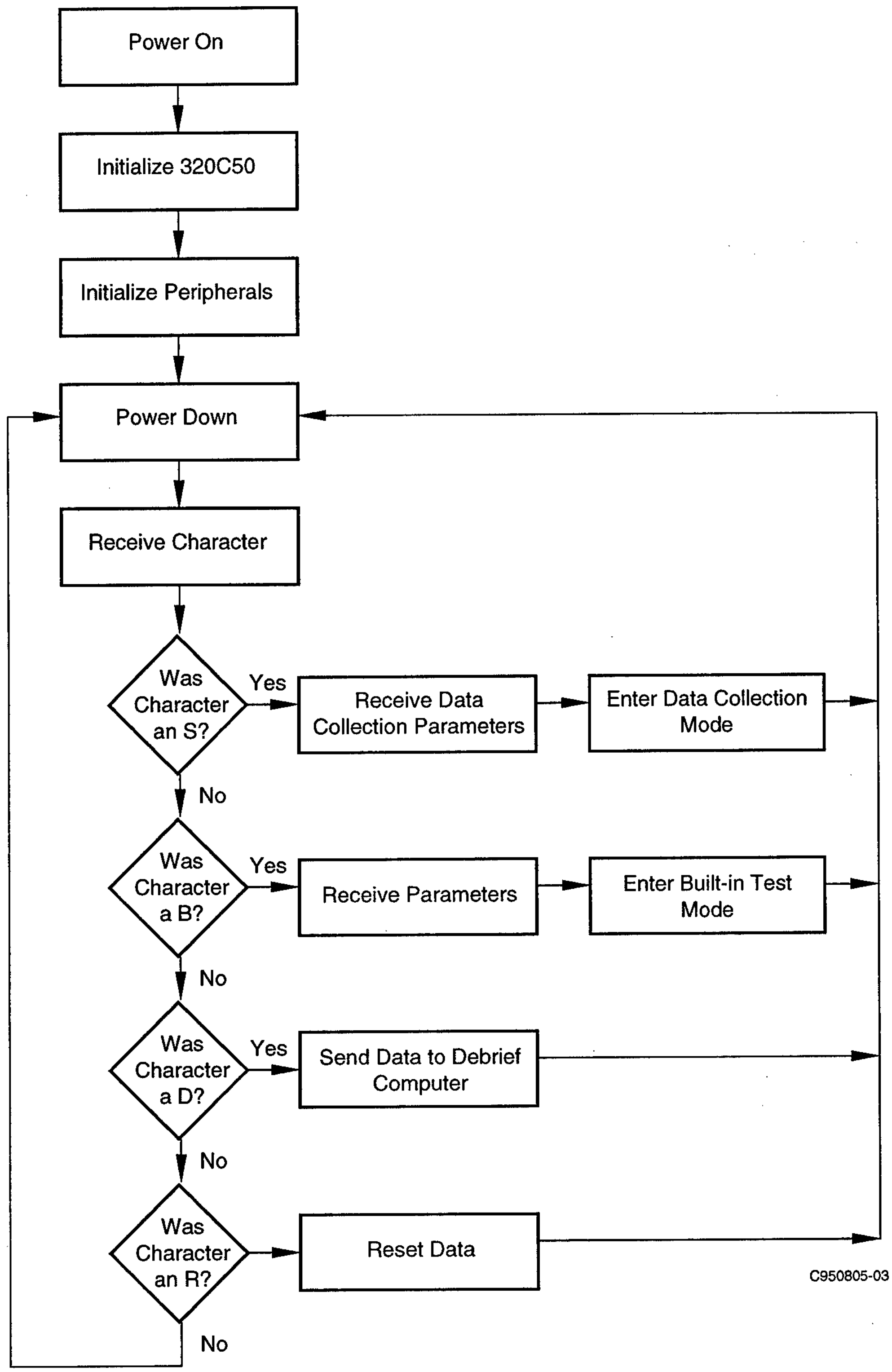


Figure 5-1. Standby Mode

Shock Detector Source determines which tri-axial accelerometer block, either external or internal, is used as the input device for the shock detector circuitry. This selection is necessarily identical to the Vibration Monitor Source selection.

Minimum Shock Threshold is a software-selectable filter that determines what calibrated level of vibration activity is considered a shock to the physical shock recording routine. The level at which one considers a shock to be a significant event during a mission can be selected. The threshold for recording of a shock in the data memory can be set to any integer between 3 and 100 G. Any shocks that occur with a magnitude below the selected threshold will be discarded.

Vibration Monitor Source determines which tri-axial accelerometer block, either external or internal, is used as the input device for the vibration recording circuitry. This selection is necessarily identical to the Shock Detector Source selection.

Vibration Zero-Order Predictor Delta determines the threshold delta used by each of the bin predictors on each of the three axes of vibration monitoring. The vibration data for each frequency bin of the fast Fourier transformation (FFT) is stored every time the magnitude of vibration at that frequency changes by this fixed amount.

Temperature Sources selects two of the three possible temperature transducer sources for monitoring during data collection (remote, surface, or ambient).

Temperature Sampling Rate (Active Mode) determines how often temperature samples from the selected temperature sensors are sent to the temperature zero-order predictors while the EDM module is in Active Data Collection Mode. Active and Sleep Data Collection Modes are described later.

Temperature Sampling Rate (Sleep Mode) determines how often temperature samples from the selected temperature sensors are sent to the temperature zero-order predictors while the EDM module is in Sleep Data Collection Mode.

Temperature Zero-Order Predictor Level determines what delta value is used in the temperature data compression predictors. The new temperature is not stored in data memory if the temperature has not changed by more than this level from the previous stored value. A value of 5 degrees is suggested for most applications.

Voltage Transient Source selects which probe, either AC or DC, the transient detector monitors during data collection. The selected probe determines which signal presence causes the EDM to enter Active Data Acquisition. Additionally, the minimum magnitude of voltage transients needed to cause the transient detector to record the voltage spike as a transient is selected from the three listed magnitudes. This software-selectable filter helps curtail the storage of transient data that may not be considered eventful from a maintenance perspective.

Humidity (Analog Voltage) Delta sets the delta value of the zero-order predictor used to filter data coming in from the humidity sensor. When the humidity port is used as a general analog voltage recorder, the value of the delta is stated in volts. Both the units of humidity (relative %) and analog voltage (volts) are listed among the choices. A value of 5% relative humidity is suggested for most applications.

Initialize Data Memory option clears the data files internal to the EDM nonvolatile memory. The user is given an opportunity to cancel this option before actual erasure.

Time and Date allows the user to input the current time and date. This option changes the internal clock on the host PC. The current time and date are downloaded along with all the other data collection parameters. The EDM then keeps track of the current time using the 1-sec interrupt ,which is generated by the real-time clock integrated circuit.

Data collection mode is entered from Standby Mode by selecting the Start EDM Data Collection line from the host PC in the Debrief/Configuration setup. A top-level flow diagram for the Data Collection Mode is shown in Figure 5-2. The data collection parameters are downloaded from the host PC at the start of every Data Collection Mode. Power interruptions experienced after the Data Collection Mode has been entered will result in a loss of real time and force the EDM back into Standby Mode.

There are two submodes of data collection while the EDM is in Data Collection Mode: active and sleep. Device operation changes between these two modes based on the status of the selected AC or DC line power presence detector. When power is detected on the selected line (AC or DC), the EDM Module enters the Active Data Collection Mode. When the sensed line indicates that no power is present, the device remains in Sleep Data Acquisition Mode. The EDM will remain in Active Mode after sensed power has been removed until the vibration sensors detect no movement, at which time Sleep Mode will be reentered.

In Sleep Data Acquisition Mode, the EDM module processor places the system in a low-power state and wakes up once a second to determine whether or not to enter Active Data Collection mode and to record events on the temperature sensors, humidity/analog voltage sensor, shock detectors, or transient detectors according to the parameters of data collection. In Sleep Mode, the selected temperature transducers are sampled according to the Sleep Temperature Sampling Rate set in the configuration section, and then filtered through the zero-order data predictors.

In Active Data Acquisition Mode, the EDM module records events on the temperature sensors, humidity sensor, shock detectors, or transient detectors according to the parameters of data collection, and additionally performs a continuous real-time 256-point FFT on each of the three axial components of the selected internal or external accelerometers. The output from each of the bins of the FFT are further filtered by zero-order data predictors according to the parameters set in the configuration section. Bins are the discrete frequency outputs of an FFT. There is one zero-order predictor used for each recorded FFT bin, and there are a total of three bins at each frequency, one for each axial channel. Finally, the temperature sampling period is adjusted to the rate set in the configuration section corresponding to Active Temperature Sampling Rate. Peak data is maintained in a large table stored in nonvolatile data space in both modes.

The vibration, humidity (analog voltage), and temperature data collection algorithms use zero-order data predictors to filter and compress collected data for storage. These predictors work by defining a magnitude threshold above and below a recorded sample that must be exceeded before another sample is recorded. Each sample has an associated time-stamp that is recorded at the time of occurrence so that a real-time format graph of the data progression can be reconstructed from the stored data. In all three data type cases, the threshold magnitude (predictor delta) value used by the predictor is software-selectable via the configuration section. See Appendix D for a more complete review of zero-order predictors.

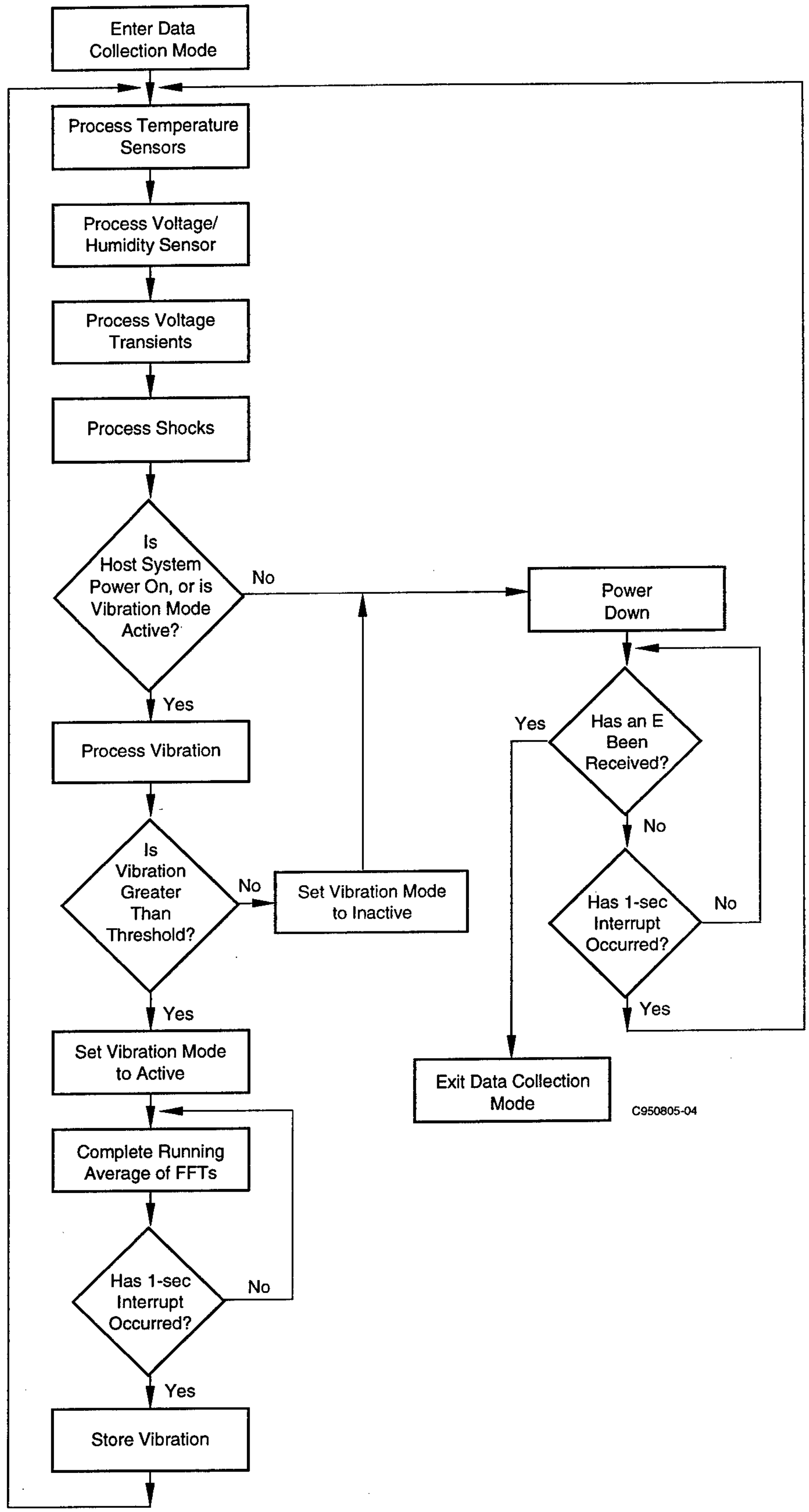


Figure 5-2. Data Collection Mode

The EDM has three interrupts: RS-232, RTC, A to D. The interrupts are individually enabled or disabled depending on the mode the EDM is currently in. During the Active Data Collection Mode, the A to D interrupt is always active and sampling the data 100% of the time. During the Sleep Data Collection Mode, the A to D is active at the start of the 1-sec interval; if no data is present, the A to D is powered down until the next 1-sec cycle. The transient and shock detectors retain their respective maximum values between sampling intervals.

5.3 Data Debrief

The EDM is debriefed from Standby Mode, the Debrief EDM main option is selected using the host computer and the contents of the EDM module data memory are written to the unformatted file named on the File Name for Debrief Data line. The default name for this file is *qratdata.dta*, but any DOS filename may be used. The file then can be processed by the host computer to format the data for display.

5.3.1 File Parsing Software

The debrief data file (*qratdata.dta*) is parsed into *DaDisp* data files by the program *qratform.exe*. This procedure takes place in a DOS shell and also creates the peak data file *qratdata.pek*. The thirteen *DaDisp* formatted files created are listed in table 5-6 below.

Table 5-6. *DaDisp* Formatted Data Files

Data File Name	Data Description
QRATTMP1.DSP	Ambient Temperature Data
QRATTMP2.DSP	Surface Temperature Data
QRATTMPX.DSP	Remote Temperature Data
QRATPWR.DSP	AC or DC Power ON Data
QRATACTR.DSP	AC Transient Data
QRATDCTR.DSP	DC Transient Data
QRATSHKX.DSP	Physical Shock Data (X axis)
QRATSHKY.DSP	Physical Shock Data (Y axis)
QRATSHKZ.DSP	Physical Shock Data (Z axis)
QRATVOLT.DSP	Humidity/Analog Voltage Data
QRATVIBX.DSP	Vibration Data (X axis)
QRATVIBY.DSP	Vibration Data (Y axis)
QRATVIBZ.DSP	Vibration Data (Z axis)

Each of the formatted data files contains a header that gives filename, date, and other general information about the file. After the header, a number of data elements are listed in conjunction with their timestamp. The timestamp is given in seconds elapsed since 1970 (decimal format), and in many cases it is easiest to program *DaDisp* or whatever data display program employed, to subtract off the time of mission start and display the data in relative time units, but the choice of relative vs. absolute time is left to the user.

Figure 5-3 below shows the file qratvibz.dsp that was created during an EDM test. The file is formatted as a DaDisp input file, and the first nine lines correspond to DaDisp required parameters. Each non-filtered event has been recorded along with its associated timestamp. Again, the timestamp is stated in seconds elapsed since the year 1970. During this constant-magnitude test the frequency of sinusoidal vibration began at 1000 Hz, was adjusted to 500 Hz, 2000 Hz, 800 Hz, and finally 100 Hz. There is a zero-order predictor operating on each of the discrete frequency bins recorded by the FFT. The output samples of each of these predictors are placed in the vibration data file. Note that most of the transitions took place during an FFT calculation, and in these cases the total energy of the system has been temporarily shared between the two transitional frequencies. As stated in the file header, the three rows of numbers correspond to: time stamp, frequency, and magnitude. The magnitude is given as uncalibrated LSBs and must be multiplied by the Vibration Scale Factor given in the calibration file to obtain the units of G squared per Hertz As the magnitude values in each frequency bin change (in excess of the predictor delta) the new values are stored in the data file. If a wider spectrum were present, one would see the non-zero magnitudes recorded in the data file at their respective bin frequencies and times of occurrence. And subsequent changes in magnitude (in excess of the predictor deltas) would also be recorded. A review of zero-order predictors is provided in appendix D

```
DATASET vibration_z
VERSION 1
NUM_SERIES 3
STORAGE_MODE interlaced
SERIES vibz_time,vibz_freq,vibz_value
VERT_UNITS S,Hz,G
HORZ_UNITS S
COMMENT vibration z
DATA
791829030 1000   715
791829050  500   359
791829050 1000   356
791829051  500   673
791829051 1000     0
791829064  500    87
791829064 2000   514
791829066  500     0
791829066 2000   650
791829078  800   713
791829078 2000     0
791829090   75   111
791829090  100   269
791829090  125    72
791829090  775    37
791829090  800   420
791829090  825    34
791829091   75     0
791829091  100   665
791829091  125     4
791829091  775     0
791829091  800     0
791829091  825     0
791829093  100   631
791829106  100   665
```

Figure 5-3. Formatted *qratvibz.dsp* Data File

In the case of a temperature or humidity file, there are only two columns of data: a time stamp and magnitude. As is the case with the frequency recorder, the initial value of the measurement is stored in the data file along with a time stamp, and then only changes in magnitude that exceed the predictor delta are recorded.

5.3.2 Postprocessing/Data Display Software

The data collected by the EDM Module is parsed into thirteen data files during the debrief and formatting procedure by the provided DOS executable *qratform.exe*. These data files are formatted as input files for the post-processing data display program *DaDisp* running on the laptop host PC. *DaDisp*, short for data display, is a program that allows complex manipulation and display of many different sets of data in traditional scientific formats. *DaDisp* was selected as a display platform because of its vast array of data display options. Specifically, it provides convenient functions for presenting linear time plots and frequency spectrums. Several macro and command files have been written for the *DaDisp* system and can be used as examples in the production of display and analysis windows (worksheets). These files are commented and are intended to be used as templates in the production of similar command structures by the user to allow tailored data presentation best suited for the particular QRAT application. These command files were written for a version of *DaDisp* (3.0) that has been since superseded (by 3.01D). Although the newest version of *DaDisp* was purchased for the deliverable item, the command files were not fully updated to function in the new *DaDisp* environment because they still succeed in performing their prescribed functions as example and template files. It is left to the user to create those exact display functions which best suit the particular application of the QRAT. To this end, a full set of *DaDisp* documentation manuals has been included.

5.3.3 Peak Data Storage Software

Peak data collected by the EDM is stored in nonvolatile memory. After debrief and data formatting, a file named *qratdata.pek* is created that contains the formatted peak data values for each of the sensor sources. Figure 5-4 contains a typical formatted peak data file. Note that the file format is static, and in some cases, depending on which sensors were active during data collection, certain data items in the peak data file will be invalid. This would be the case if external vibration were recorded and the external accelerometer block was not hooked up. Be careful to consider the sensor scheme when interpreting the peak data file. Temperature measurements are given in degrees Celsius. The data under the humidity/voltage heading corresponds to the calibration values stated in the calibration file (section 5.5). The software does not automatically detect the proper units, instead it is left to the user to determine whether the conversion performed results in a measure of volts or relative humidity. Shock is recorded in the units of peak G; where G is the average value of the acceleration due to gravity at sea level. The peak FFT vibration table is formatted in increments of 25Hz beginning in the upper left hand corner and continuing right for each line. The table legend on the left lists only every fourth frequency bin, but in actuality all of the bins are included in the file. For example, line two of the table includes the 100, 125, 150, and 175 Hz bins. The peak magnitude of the frequency bins is stated in milli- (multiplied by 1000) and given in the units of G squared per Hertz.

```
Ambient Temperature
Maximum = 24 degrees C at Thu Feb 02 11:26:13 1995
Minimum = 24 degrees C at Thu Feb 02 11:26:08 1995

Surface Temperature
Maximum = 22 degrees C at Thu Feb 02 11:26:23 1995
Minimum = 22 degrees C at Thu Feb 02 11:26:08 1995

Humidity/voltage
Maximum = 56 at Thu Feb 02 11:26:14 1995
Minimum = 56 at Thu Feb 02 11:26:19 1995

Shock X axis
Maximum = 10 G's at Thu Feb 02 11:26:18 1995

Shock y axis
Maximum = 44 G's at Thu Feb 02 11:26:18 1995

Shock Z axis
Maximum = 24 G's at Thu Feb 02 11:26:18 1995

Maximum Positive AC Transient
Maximum = 0000 Volts at Thu Feb 02 11:26:06 1995
Maximum Negative AC Transient
Maximum = 0000 Volts at Thu Feb 02 11:26:08 1995

X Axis Vibration Maximum's (*10^-3 G^2/HZ)

   0 Hz  0.00000      0.00000      0.00000      0.00000
 100 Hz  0.00000      0.00000      0.00000      0.00000
 200 Hz  0.00000      0.00000      0.00000      0.00000
 300 Hz  0.00000      0.00000      0.00000      0.00000
 400 Hz  0.00000      0.00000      0.00000      0.00000
 500 Hz  0.00000      0.00000      0.00000      0.00000
 600 Hz  0.00000      0.00000      0.00000      0.00000
 700 Hz  0.00000      0.00000      0.00000      0.00000
 800 Hz  0.00000      0.00000      0.00000      0.00000
 900 Hz  0.00000      0.00000      0.00000      0.00000
1000 Hz  0.00000      0.00000      0.00000      0.00000
1100 Hz  0.00000      0.00000      0.00000      0.00000
1200 Hz  0.00000      0.00000      0.00000      0.00000
1300 Hz  0.00000      0.00000      0.00000      0.00000
1400 Hz  0.00000      0.00000      0.00000      0.00000
1500 Hz  0.00000      0.00000      0.00000      0.00000
1600 Hz  0.00000      0.00000      0.00000      0.00000
1700 Hz  0.00000      0.00000      0.00000      0.00000
1800 Hz  0.00000      0.00000      0.00000      0.00000
1900 Hz  0.00000      0.00000      0.00000      0.00000
2000 Hz  0.00000      0.00000      0.00000      0.00000
2100 Hz  0.00000      0.00000      0.00000      0.00000
2200 Hz  0.00000      0.00000      0.00000      0.00000
2300 Hz  0.00000      0.00000      0.00000      0.00000
2400 Hz  0.00000      0.00000      0.00000      0.00000
2500 Hz  0.00000

Y Axis Vibration Maximum's (*10^-3 G^2/HZ)

   0 Hz  0.00000      0.00000      0.00000      0.00000
 100 Hz  0.00000      0.00000      0.00000      0.00000
 200 Hz  0.00000      0.00000      0.00000      0.00000
 300 Hz  0.00000      0.00000      0.00000      0.00000
 400 Hz  0.00000      0.00000      0.00000      0.00000
```

Figure 5-4. Formatted *qratdata.pek* Data File (cont. next page)

```
 500 Hz  0.00000      0.00000      0.00000      0.00000
 600 Hz  0.00000      0.00000      0.00000      0.00000
 700 Hz  0.00000      0.00000      0.00000      0.00000
 800 Hz  0.00000      0.00000      0.00000      0.00000
 900 Hz  0.00000      0.00000      0.00000      0.00000
1000 Hz  0.00000      0.00000      0.00000      0.00000
1100 Hz  0.00000      0.00000      0.00000      0.00000
1200 Hz  0.00000      0.00000      0.00000      0.00000
1300 Hz  0.00000      0.00000      0.00000      0.00000
1400 Hz  0.00000      0.00000      0.00000      0.00000
1500 Hz  0.00000      0.00000      0.00000      0.00000
1600 Hz  0.00000      0.00000      0.00000      0.00000
1700 Hz  0.00000      0.00000      0.00000      0.00000
1800 Hz  0.00000      0.00000      0.00000      0.00000
1900 Hz  0.00000      0.00000      0.00000      0.00000
2000 Hz  0.00000      0.00000      0.00000      0.00000
2100 Hz  0.00000      0.00000      0.00000      0.00000
2200 Hz  0.00000      0.00000      0.00000      0.00000
2300 Hz  0.00000      0.00000      0.00000      0.00000
2400 Hz  0.00000      0.00000      0.00000      0.00000
2500 Hz  0.00000

Z Axis Vibration Maximum's (*10^-3 G^2/HZ)

   0 Hz  0.00000      0.00000      0.00000      0.00000
 100 Hz  0.00000      0.00000      0.00000      0.00000
 200 Hz  0.00000      0.00000      0.00000      0.00000
 300 Hz  0.00000      0.00000      0.00000      0.00000
 400 Hz  0.00000      0.00000      0.00000      0.00000
 500 Hz  0.00000      0.00000      0.00000      0.00000
 600 Hz  0.00000      0.00000      0.00000      0.00000
 700 Hz  0.00000      0.00000      0.00000      0.00000
 800 Hz  0.00000      0.00000      0.00000      0.00000
 900 Hz  0.00000      0.00000      0.00000      0.00000
1000 Hz  0.00000      0.00000      0.00000      0.00000
1100 Hz  0.00000      0.00000      0.00000      0.00000
1200 Hz  0.00000      0.00000      0.00000      0.00000
1300 Hz  0.00000      0.00000      0.00000      0.00000
1400 Hz  0.00000      0.00000      0.00000      0.00000
1500 Hz  0.00000      0.00000      0.00000      0.00000
1600 Hz  0.00000      0.00000      0.00000      0.00000
1700 Hz  0.00000      0.00000      0.00000      0.00000
1800 Hz  0.00000      0.00000      0.00000      0.00000
1900 Hz  0.00000      0.00000      0.00000      0.00000
2000 Hz  0.00000      0.00000      0.00000      0.00000
2100 Hz  0.00000      0.00000      0.00000      0.00000
2200 Hz  0.00000      0.00000      0.00000      0.00000
2300 Hz  0.00000      0.00000      0.00000      0.00000
2400 Hz  0.00000      0.00000      0.00000      0.00000
2500 Hz  0.00000
```

Figure 5-4. Formatted *qratdata.pek* Data File (concluded)

5.4 Built-in Test Mode

The processor performs a built-in digital test at power-up and will set the fault indicator to a visible state if any system faults are detected. Analog system tests can also be performed by the user. From Standby Mode in the Debrief/Configuration hardware setup, the EDM can be placed in Built-in Test Mode. This test mode allows all of the primary analog and processing functions to be viewed concurrently, and any data discrepancies become detectable.

All 16 real-time data values processed by the EDM module are displayed. The transient and shock peak detectors can be reset by pressing 'r' while in the BIT Mode. Entering a 'q' will put the EDM back in Standby Mode. Table 5-7 shows typical values for the 16 EDM data items with the device at rest in a typical room environment. The values are displayed as uncalibrated (LSB) hexadecimal integers with a range from 000 to fff.

This test mode should be used to verify the integrity of the incoming sensor signals. An error condition will exist when the device, placed in a typical room environment (22 degrees C, 40% RH, no transient voltage surges, and no motion), displays values outside of a 10% range from the typical values given in the table. This mode is also useful for verifying that the sensor systems are properly connected. If for example, the Vibration X data item were at level 000 it is likely that the accelerometer is not connected properly.

Table 5-7. Built-in Test Typical Real-Time Values

Data Item	Typical Value
Vibration X	900
Vibration Y	900
Vibration Z	700
Shock X	005
Shock Y	005
Shock Z	005
DC Pos Transient	900
DC Neg Transient	900
AC Pos Transient	900
AC Neg Transient	900
Remote Temperature	b60
Surface Temperature	b60
Ambient Temperature	b60
DC Power	000
AC Power	000
Humidity	900

In addition to the real-time data display, the maximum magnitude FFT bin for each of the three axes of selected vibration is displayed. The peak value of recorded shock is also held for user inspection. Many times it is necessary to reset the shock detectors immediately after entering Built-in Test Mode (a function performed automatically during data acquisition) because transitional values may be recorded as the analog circuits come on line. Table 5-8 shows typical values (in LSBs) for the processing data items (FFT and peak shock) when the EDM is at rest in a typical room environment.

Table 5-8. Built-in Test Typical Processed Values

Data Item	Typical Value
Maximum Frequency Bin X-Axis	000
Value	000
Maximum Frequency Bin Y-Axis	000
Value	000
Maximum Frequency Bin Z-Axis	000
Value	000
Peak Shock X-Axis	005
Peak Shock Y-Axis	005
Peak Shock Z-Axis	005

The values contained in table 5.8 can be used by the user to verify the operation of the processing functions. An error condition will exist when the device, placed in a typical room environment (22 degrees C, 40% RH, no transient voltage surges, and no motion), displays values outside of a 10 LSB range from the typical values given in the table. This mode is also useful in verifying the mounting of the motion sensor(s). By providing some non-zero level of motion input, the user will see activity in real time using this display.

5.5 Calibration Software

Collected data is calibrated from the stored LSB values to real units during the file parsing operation (running of *qratform.exe*). Calibration information is read from calibration files during data file output building. There is one calibration file for each EDM module: *qratcal1.edm*, *qratcal2.edm*, and *qratcal3.edm*. The file parsing program, *qratform.exe*, extracts EDM module serial number information from the debrief data file, *qratdata.dta*, and accesses the proper calibration file during formatting. Table 5-9 lists the format of the calibration files, each item takes one line in the file and is of the numerical format listed in the table. The data contained in these files were generated during final calibration testing and in most cases should not be modified. It was included in this manual primarily because it provides some insight into the operation of the system which may help clarify implementation issues. The exception to this is in the calibration of the humidity sensor port when it is used as an analog voltage sensor. In this case the user will need to provide Offset and Scale values (in replacement of the humidity sensor calibration values) consistent with the source of the analog signal.

Calibration of the units took place during final testing. The procedures used for each sensor type are explained in section 6. If calibration is needed due to new sensors or other system changes, the values of calibration can be obtained by using the built-in-test routines and reading out direct A/D channel values for the sensor to be calibrated under varying, referenced environmental conditions. This procedure is unique to each sensor type, and sufficient data points will need to be collected to obtain accurate scale and offset parameters for the new device.

Table 5-9. Format of EDM Calibration Files

EDM Calibration File Format
Ambient Temperature Offset (Hexadecimal Integer)
Ambient Temperature Scale Factor (Real Number)
Surface Temperature Offset (Hexadecimal Integer)
Surface Temperature Scale Factor (Real Number)
Remote Temperature Offset (Hexadecimal Integer)
Remote Temperature Scale Factor (Real Number)
Humidity Offset (Hexadecimal Integer)
Humidity Scale Factor (Real Number)
Shock X axis Scale Factor (Real Number)
Shock X axis Offset (Hexadecimal Integer)
Shock Y axis Scale Factor (Real Number)
Shock Y axis Offset (Hexadecimal Integer)
Shock Z axis Scale Factor (Real Number)
Shock Z axis Offset (Hexadecimal Integer)
AC Transient Positive Scale Factor (Real Number)
AC Transient Positive Offset (Hexadecimal Integer)
AC Transient Negative Scale Factor (Real Number)
AC Transient Negative Offset (Hexadecimal Integer)
DC Transient Positive Scale Factor (Real Number)
DC Transient Positive Offset (Hexadecimal Integer)
DC Transient Negative Scale Factor (Real Number)
DC Transient Negative Offset (Hexadecimal Integer)
Vibration Scale Factor (Real Number)

Section 6
System Testing

The QRAT EDM was subjected to a number of performance tests for both calibration and acceptance. Each of the sensor systems was carefully exercised over its entire operating range. Data from these tests were accumulated and used as calibration information and for statistical analysis in performance evaluation.

6.1 Shock and Vibration Testing

To facilitate internally sensed vibration and shock testing, a number of fixtures were designed to mount the sensor and electronics package directly to a precision motion table. Different fixtures were used to impose motion on each of the orthogonally mounted accelerometers. During vibration testing, sinusoidal motion was used at several different magnitude values to record calibration values. Shock testing and calibration used a special shock waveform to stimulate the motion table and used the output of the reference accelerometer as recorded by a digital oscilloscope to determine calibration values. Figure 6-1 shows the mounting scheme used to excite the internal accelerometers of the Sensor and Electronics Package in the X-axis.

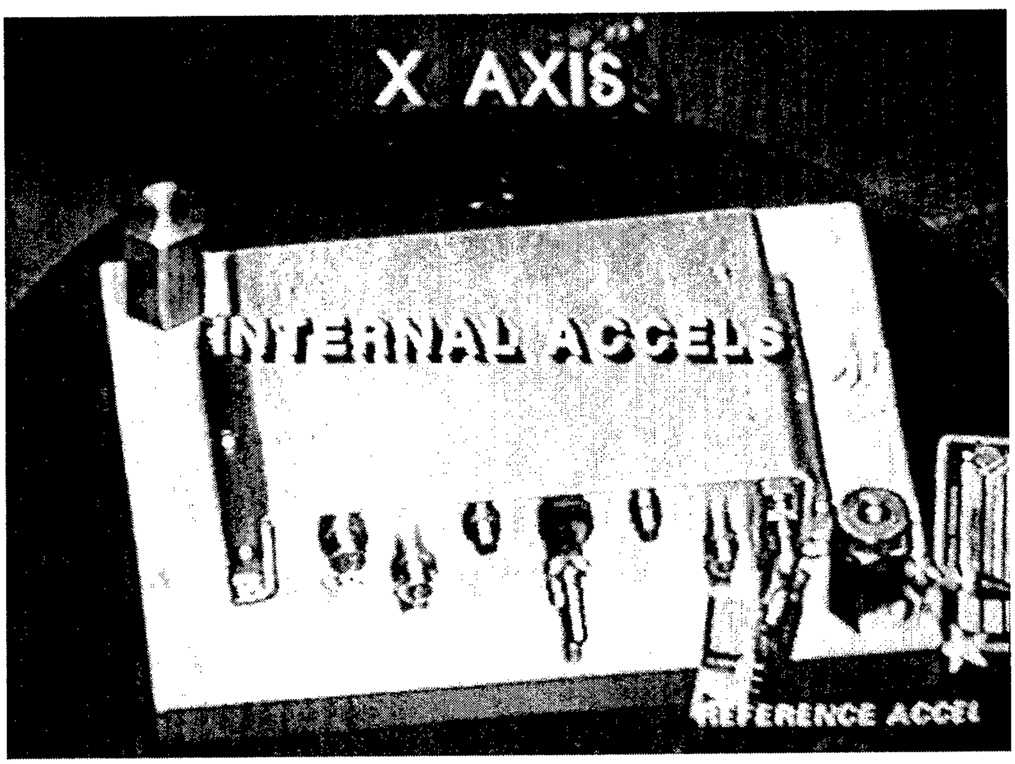


Figure 6-1. Internal Vibration and Shock Testing on X-Axis

In the lower right corner of the conversion plate shown in Figures 6-1, 6-2, and 6-3, the reference accelerometer can be seen. Opposite to it is a counterbalance used to nullify the distortion effects of unbalanced loading on the motion table. The reference accelerometer is fed into a precision charge amplification system and compressor. The outputs of these devices are used both to control the motion of the table and as a calibrated reference by which the performance of the QRAT accelerometer systems can be measured. Figure 6-2 shows a slightly different mounting orientation used to test the internal accelerometers in the Y-axis of motion. Figure 6-3 shows excitation in the Z-axis.

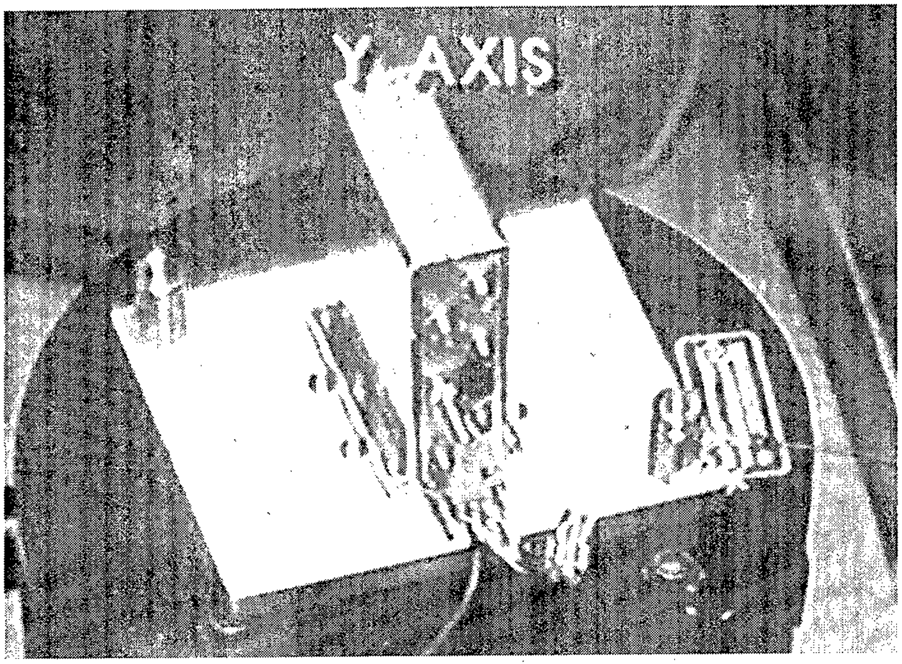


Figure 6-2. Internal Vibration and Shock Testing on Y-Axis

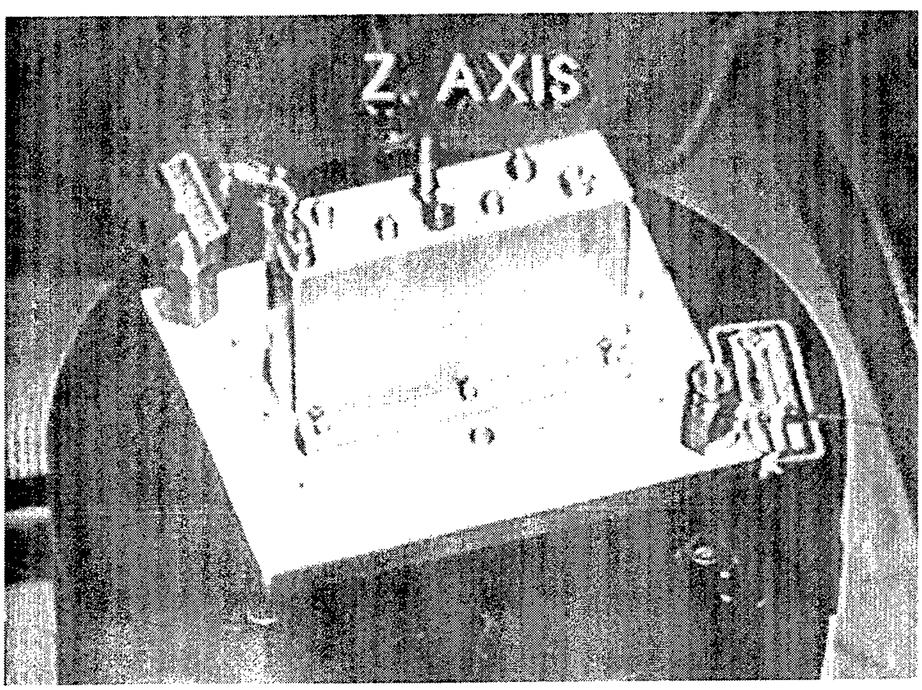


Figure 6-3. Internal Vibration and Shock Testing on Z-Axis

Similar to the internal accelerometer testing, a set of fixtures was developed to hold the external accelerometer block aligned in each of the three orthogonal planes of motion. In this case, the mounting block is attached directly to the reference accelerometer, which is in turn mounted directly to the center of the head of the motion table. This eliminates the need to balance the reference system.

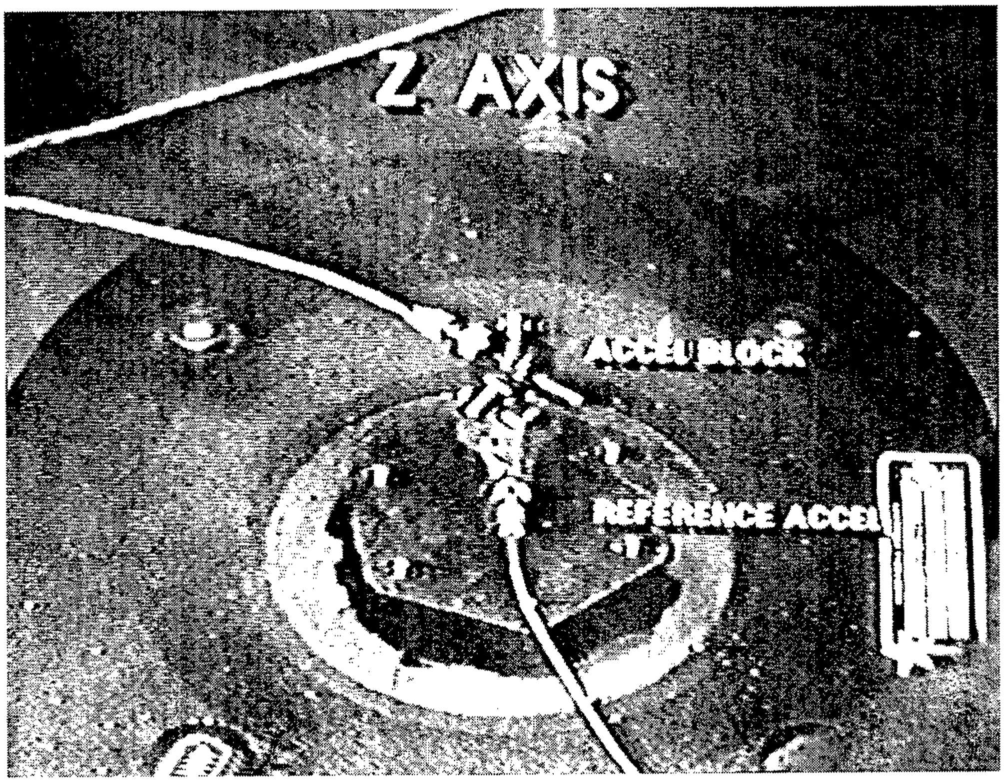


Figure 6-4. External Vibration and Shock Testing in Z Axis

In testing the external accelerometers in the Z-axis, no fixturing is necessary. The accelerometer under test is screwed directly to the top of the reference accelerometer with the assistance of a thread splicer. The resulting system, shown in Figure 6-4, is in linear balance.

In the case of X and Y axis testing, a dummy accelerometer block is used to counterbalance the mass of the remote accelerometers under test. Figure 6-5 shows the configuration of the X and Y axis test system.

Shock testing is facilitated by driving the motion table with a precision pulse generator and monitoring the output of the reference accelerometer with a digital waveform capturing oscilloscope. Post-pulse analysis allows fine adjustment of the pulse amplitude to maintain constant shock pulse amplitude. Data collected from this process is used to calibrate the shock levels recorded by the Sensor and Electronics Package. Figure 6-6 shows the pulse waveform from the reference accelerometer as it appears to the operator during the calibration procedure.

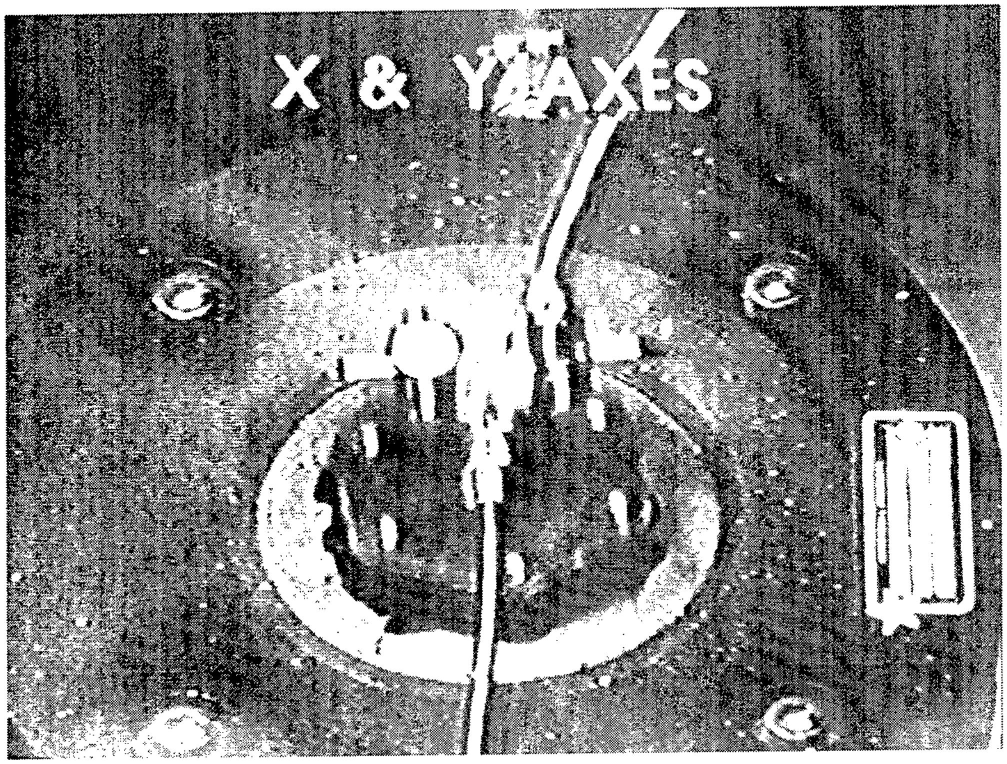


Figure 6-5. External Vibration and Shock Testing on X and Y Axes

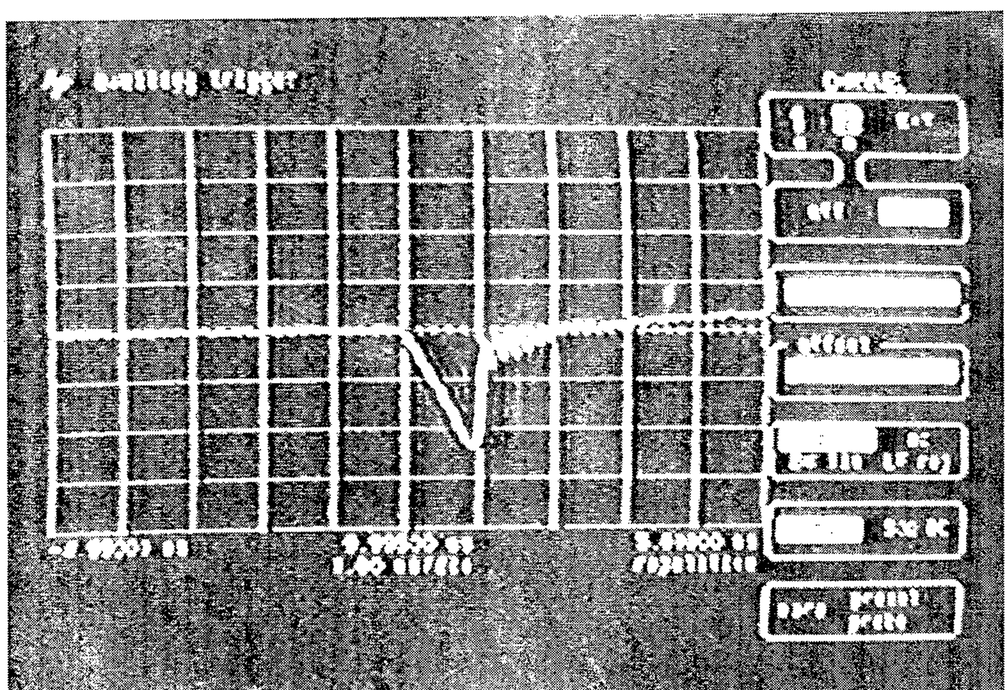


Figure 6-6. Pulse Waveform Recorded During Shock Calibration

6.2 Humidity Testing

The QRAT system humidity sensor was tested and calibrated using a manufacturer-provided system of salts and other chemical compounds. By mixing these substances in a small sealed package, different levels of calibrated relative humidity can be established. The mixing procedure allows several distinct points along the humidity spectrum to be maintained, and calibration is accomplished by combining this information with the actual output of the sensor.

The Rotronic Instrument Corporation humidity standards calibration set was used for QRAT system calibration. Fixed values of 0%, 35%, and 80% relative humidity where used to determine the first order scale and offset values inherent in the system humidity to LSBs conversion. These values are recorded in the calibration files. These tests were performed at room temperature.

6.3 Temperature Testing

Temperature testing was accomplished using a computer-controlled oven and cooling chamber. The oven uses electric heat and liquid nitrogen cooling. Long settling times in the range of hours were used when the entire Sensor and Electronics package was in the chamber. Shorter times were used when only the remote sensors were being calibrated. Exact chamber temperatures were determined using a calibration-verified Fluke model 2190A thermocouple system as a reference. Several points were captured during the test procedure to generate the first order scale and offset values inherent in the system temperature to bits conversion. These values are recorded in the calibration files.

6.4 AC/DC Probe Testing

The AC/DC sensor probe was tested using a number of high-voltage sources, amplifiers, and transient pulse generators. In the case of transients superimposed on a DC power line, the pulse generator was connected in series with a high-voltage source. The DC level of the source was established at a variety of voltages. The transient signal was introduced in magnitude steps and the output of the QRAT data recording algorithm monitored. Both positive and negative voltage transients were generated. Calibration was accomplished by adjusting software parameters to match the output of the system as recorded by a calibrated digital waveform capturing oscilloscope. An example waveform of positive transient voltages superimposed on a DC signal is shown below in Figure 6-7.

The procedure for superimposing transient voltages on an AC signal is similar to the DC case. The AC voltage is brought up to the nominal 115-V RMS, and the transients extend above or below this level. Figure 6-8 shows the superposition of positive voltage transients onto an AC voltage waveform. As was the case for the DC voltage, the resulting signals are recorded by a calibrated waveform-capturing oscilloscope for comparison with the values recorded by the Sensor and Electronics Package.

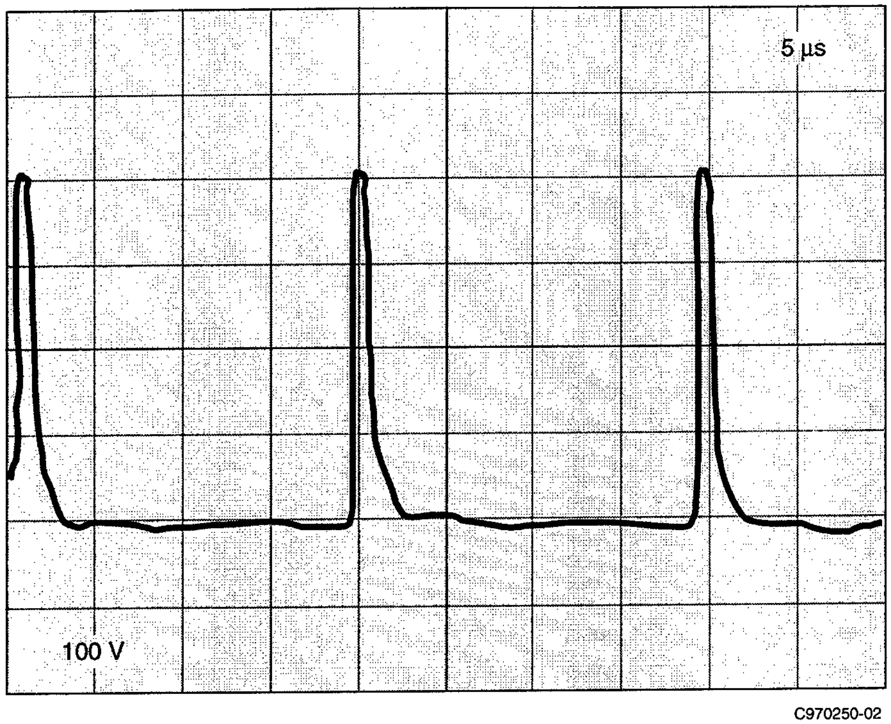


Figure 6-7. Voltage Transient Test Signal (DC).

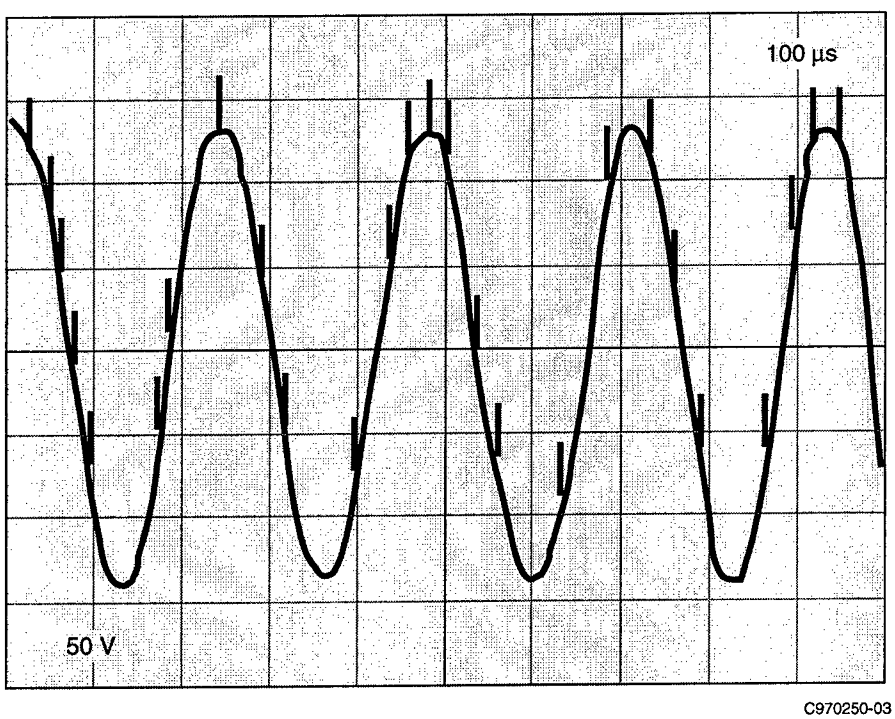


Figure 6-8. Voltage Transient Test Signal (AC)

Section 7
QRAT System Specifications

Physical Size:

Item	Value	Unit
(EDM Module) Length	3.0	Inch
(EDM Module) Height	4.0	Inch
(EDM Module) Depth	0.90	Inch
(Battery Box) Length	8	Inch
(Battery Box) Height	4	Inch
(Battery Box) Depth	9	Inch
(P-18 Box) Length	2.25	Inch
(P-18 Box) Height	1.13	Inch
(P-18 Box) Depth	1.375	Inch

System Absolute Limits:

Item	Min	Max	Nom.	Unit
System Operating Temperature	-55	+125		°C

Electrical Supply:

Item	Min	Max	Nom.	Unit
Battery Voltage (Main)			5	V
Battery Voltage (Secondary)			11	V
Battery Capacity			84	A-Hr

Temperature Sensor Characteristics (all):

Item	Min	Max	Nom.	Unit
Operating Range	-55	+150		°C
Calibration Accuracy		±0.5		°C
Linearity		±0.3		°C
Repeatability		±0.1		°C
Long Term Drift		±0.1		°C

Humidity Sensor Characteristics:

Item	Min	Max	Nom.	Unit
Operating Range	0	100		%RH
Total Accuracy	-2	+2		%RH
Linearity			±0.5	%RH
Repeatability		±0.5		%RH
Hysteresis		±0.8		% Span

Acceleration Sensor Characteristics (all):

Item	Min	Max	Nom.	Unit
Sensitivity			10	mV/g
Noise Floor		0.0020		g RMS
Peak Input		±212		g
Shock Survivability		±10000		g
Amplitude Linearity			±1	%

System Software:

Item	Min	Max	Nom.	Unit
Sampling Interval (Temperature)	1	3600		S
Sampling Rate (Vibration)			3400	Hz
Sampling Interval (Humidity)	1	3600		S

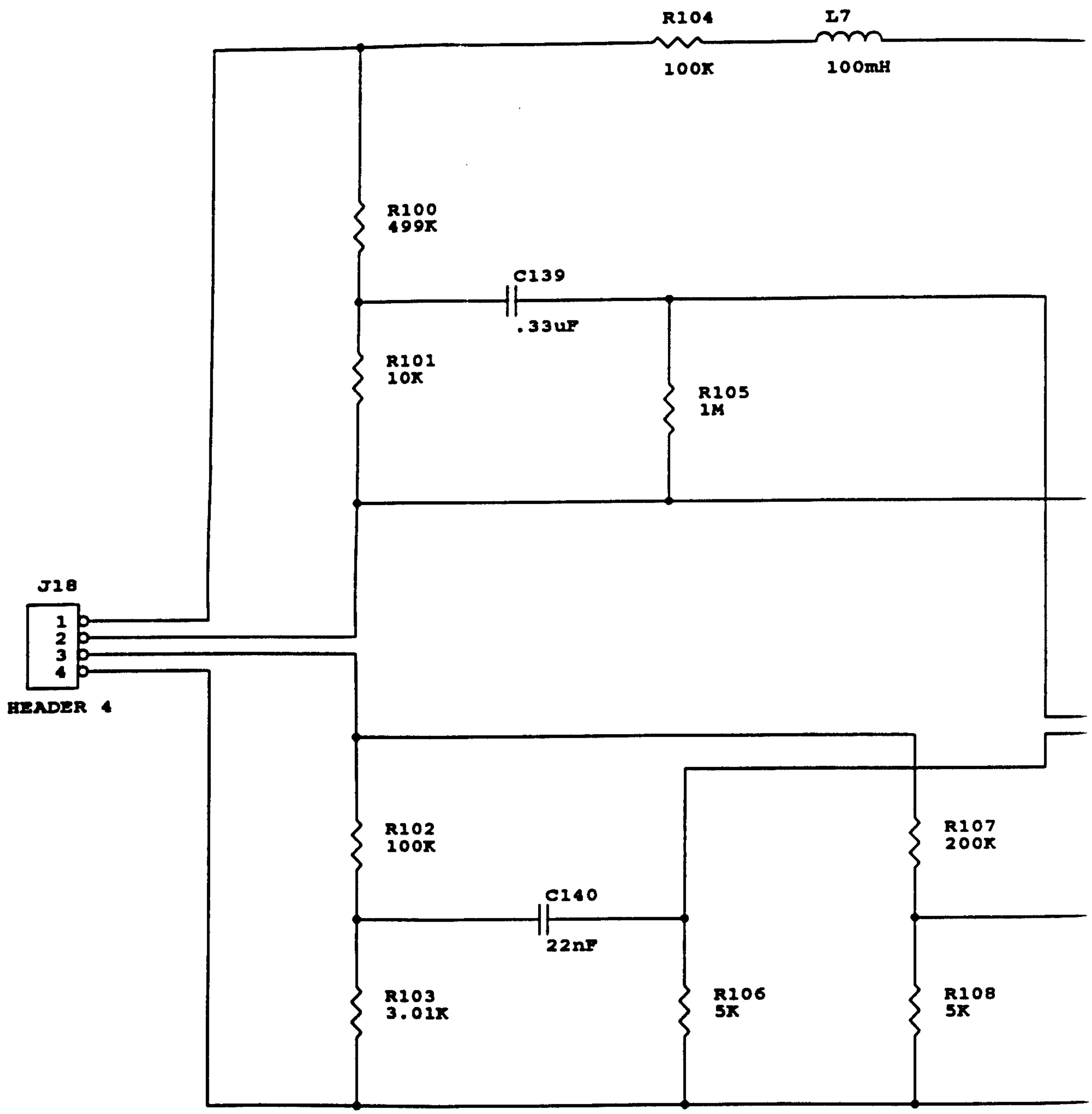
Section 8
Conclusion

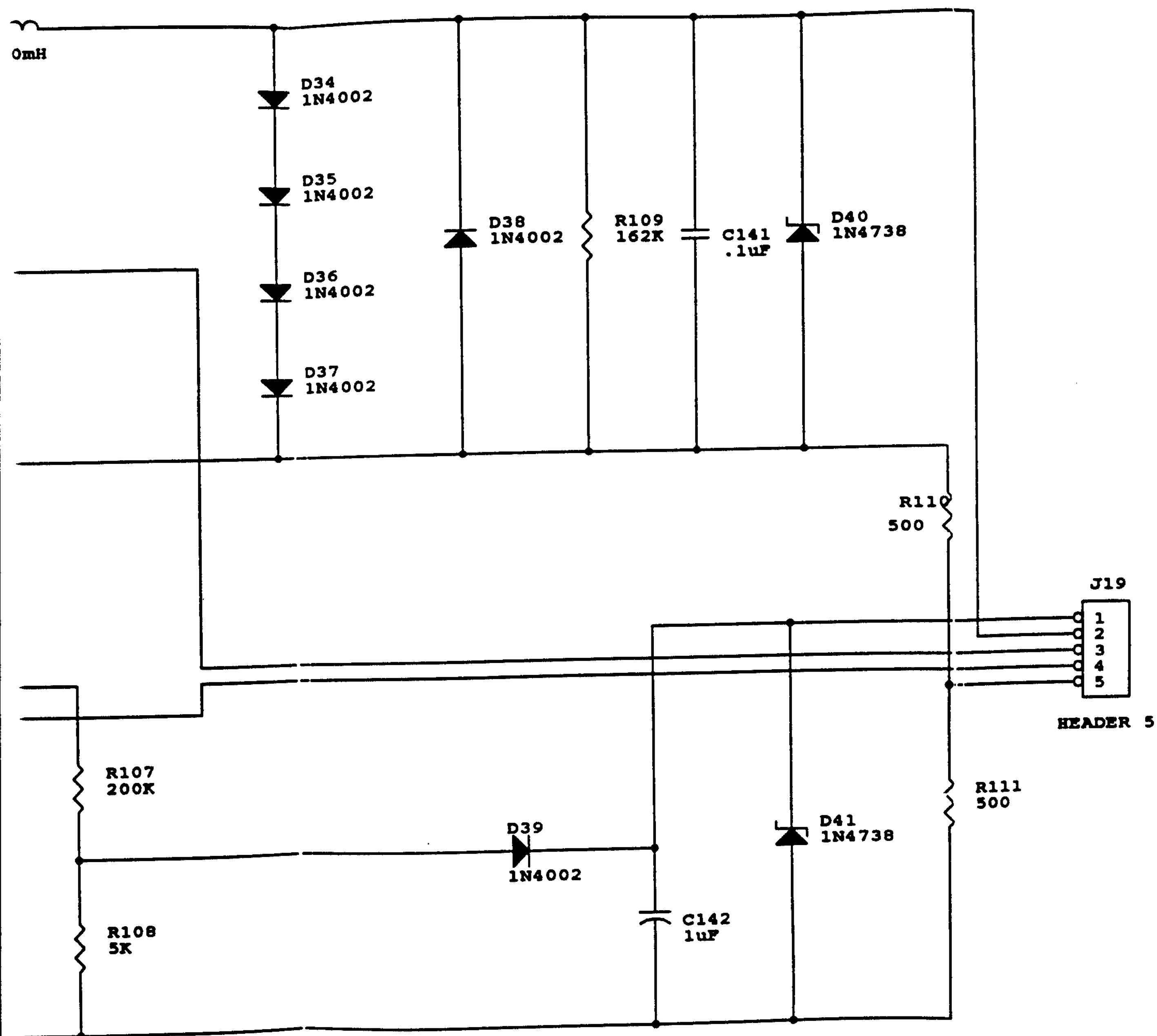
The Quick Reliability Assessment Tool Program was successful in developing a miniature device capable of recording three channels of vibration and shock as well as a number of other environmental parameters. It did this in a package size that is smaller than any other device available in the marketplace. This allows the QRAT device to be placed in avionics applications where space is at a premium. The QRAT also provides the unique capability of allowing for continuous FFT analysis of all three channels of vibration data. This unique feature is a major distinguishing characteristic for all other sensor data-logging devices.

Appendix A
Lessons Learned

The Quick Reliability Assessment Tool Program incorporated a number of new ideas that previous Time Stress Measurement Devices (TSMDs) did not have. The key new idea was that the vibrations were continuously processed. Previous designs would only take samples of the vibration waveform on which to perform the fast Fourier transformation. During this program, a great deal was learned as to how this could be processed continuously using a digital signal processor chip in a minimum parts count design. Another new idea developed on this program was the ability to switch between internal or external sensors under software command. This again was a feature that past TSMDs did not have. Another unique feature was a temperature sensor that was part of the main package but thermally isolated from it. It was intended to measure the ambient but not the case temperature. To solve this problem, a screen housing was designed to hold a temperature sensor thermally from the case. Finally, we had to develop a way to interface safely to a high-voltage AC power line for monitoring. The solution developed for this problem was an attenuator and filter assembly that mounted in the cable assembly used for interfacing to the high-voltage power line.

Appendix B
Electronic Schematic Drawings

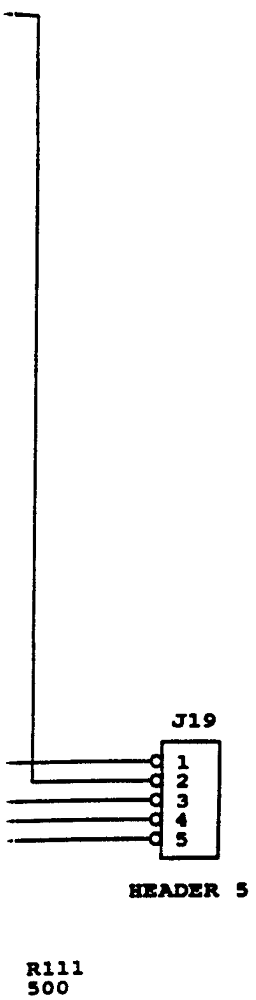

R104
100K
L7
100mH
R100
499K
C139
.33uF
R101
10K
R105
1M
J18
1
2
3
4
HEADER 4
R102
100K
R107
200K
C140
22nF
R103
3.01K
R106
5K
R108
5K



SHEET CONTAINS R100 THRU R111
SHEET CONTAINS C139 THRU C142
SHEET CONTAINS D34 THRU D41
SHEET CONTAINS J18 AND J19
SHEET CONTAINS L7

Title	AC/DC Interface	
Size B	Document Number QRAT Schematic	
Date: October 6, 1994	Sheet 1 of	

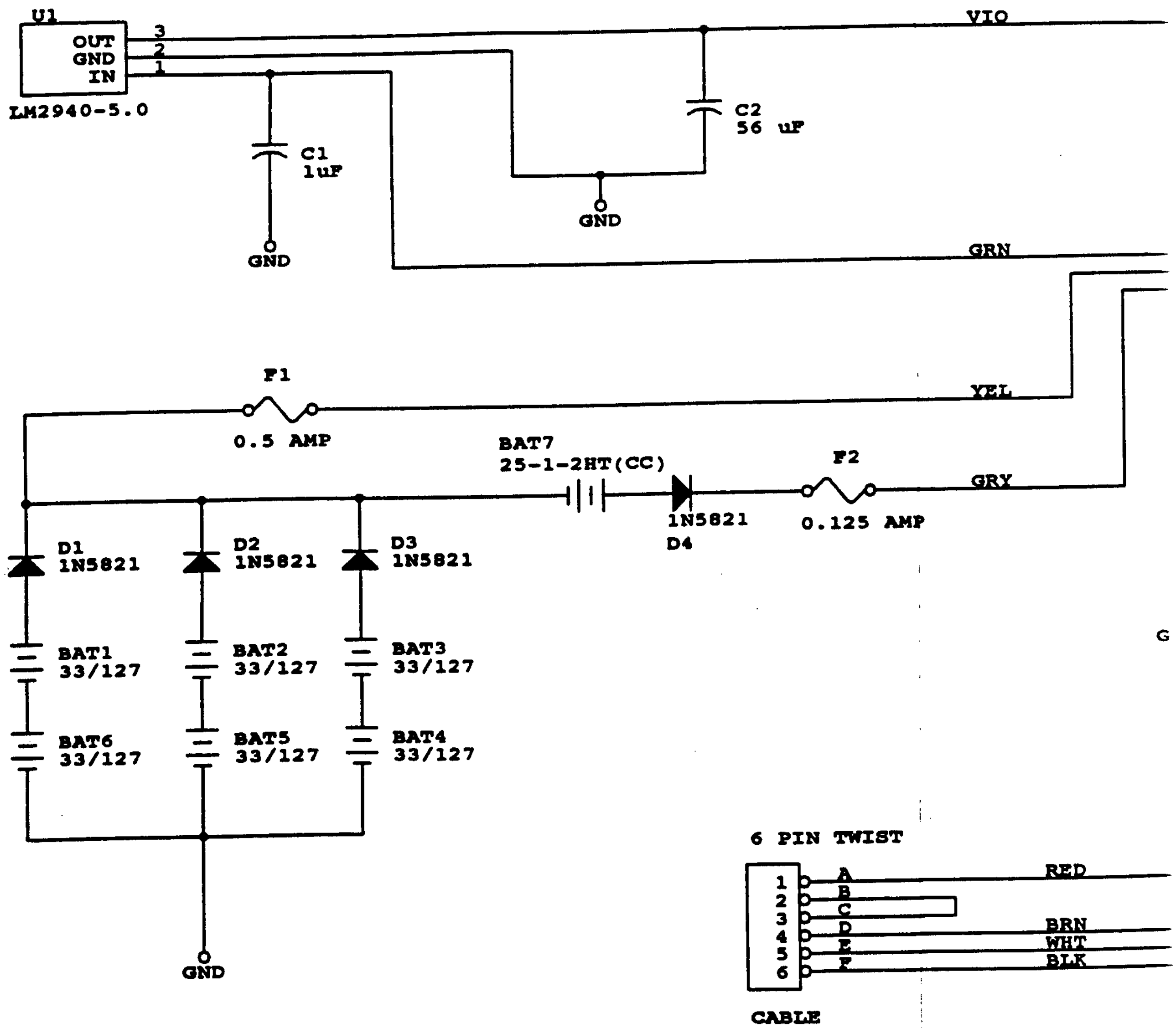
2



AC/DC Interface

Number	REV
QRAT Schematic	4.6
er 6, 1994 Sheet 1 of	6

(3)

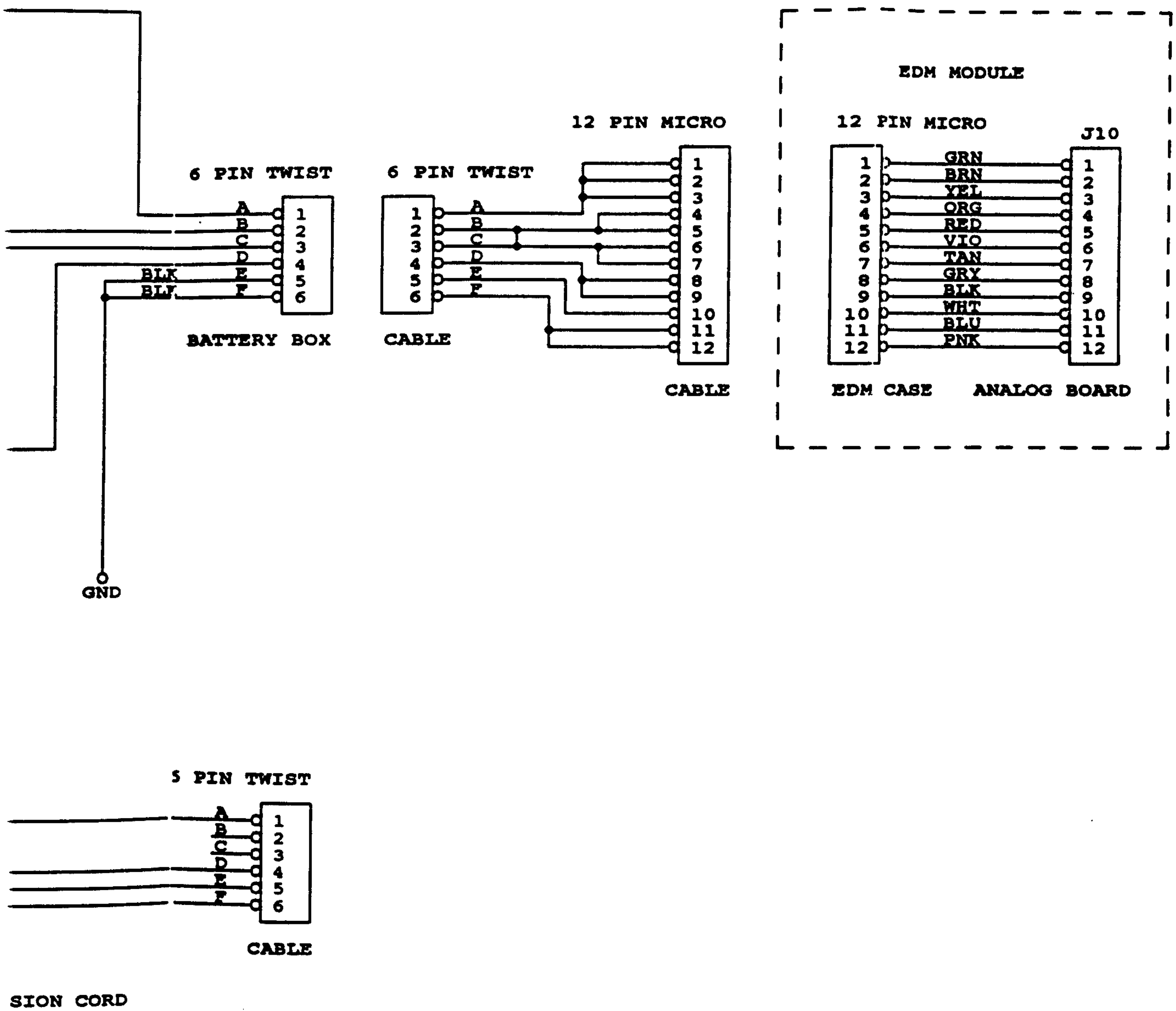


BATTERIES ARE 3.6 VOLT

FORWARD DIODE DROP = 0.35 VOLT

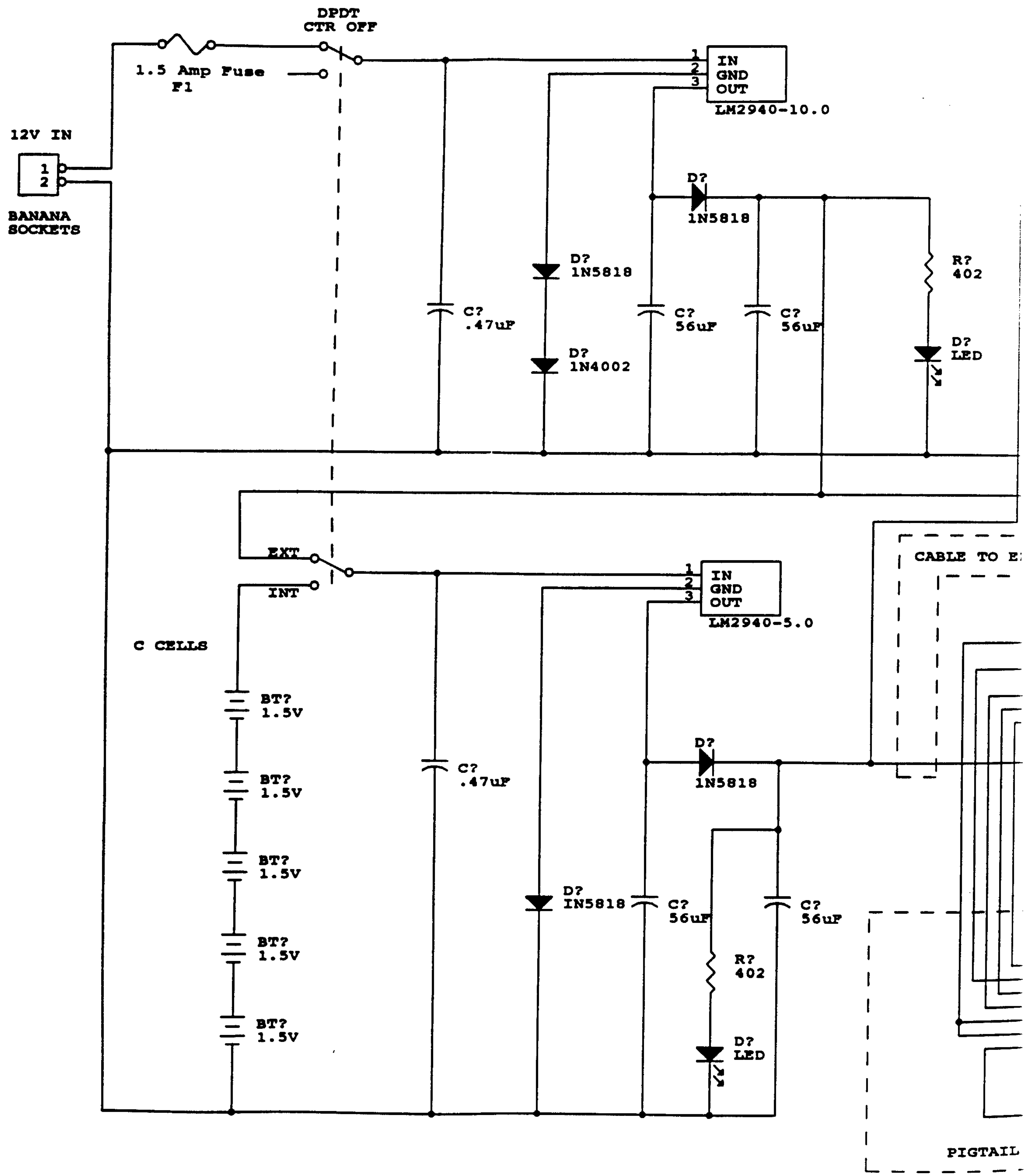
REGULATOR OUTPUT = 5 VOLT

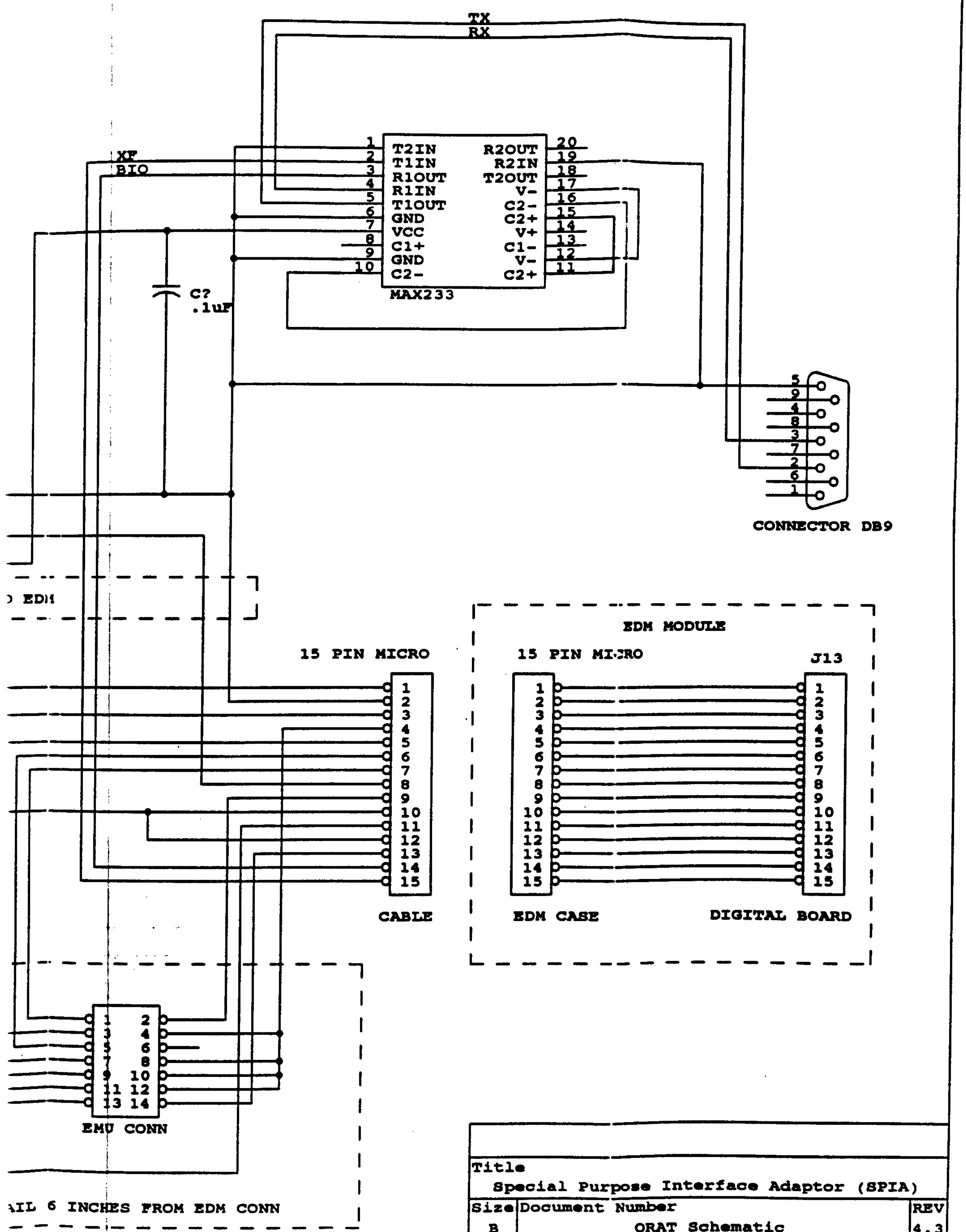
1



Title	Battery Box	
Size B	Document Number QRAT Schematic	REV 4.3
Date: February 5, 1995	Sheet 2 of 6	

2

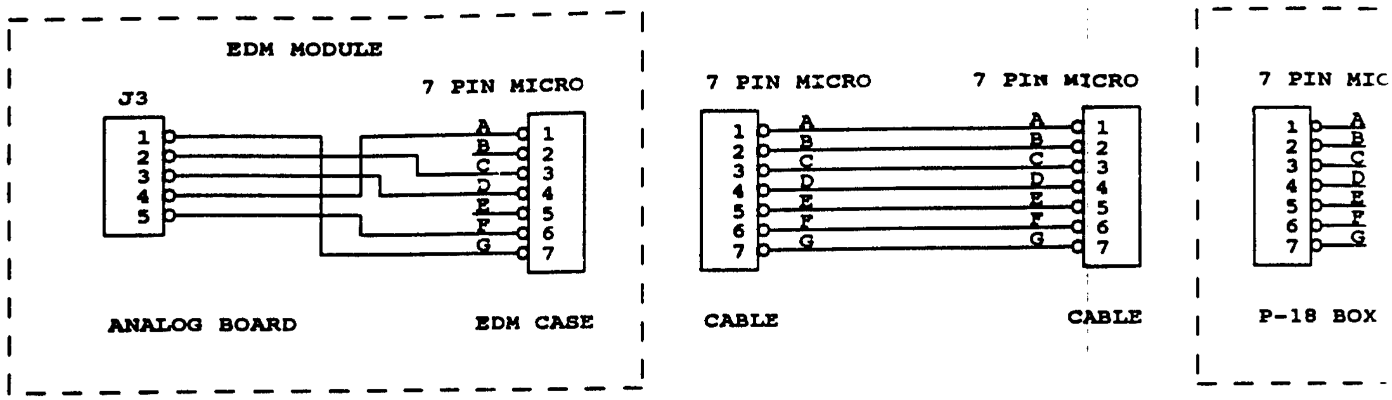

DPDT
CTR OFF
1.5 Amp Fuse
F1
12V IN
1
2
BANANA
SOCKETS
1
2
3
IN
GND
OUT
LM2940-10.0
D?
1N5818
D?
1N5818
D?
1N4002
C?
.47uF
C?
56uF
C?
56uF
R?
402
D?
LED
CABLE TO E
EXT
INT
C CELLS
BT?
1.5V
BT?
1.5V
BT?
1.5V
BT?
1.5V
BT?
1.5V
1
2
3
IN
GND
OUT
LM2940-5.0
C?
.47uF
D?
1N5818
D?
IN5818
C?
56uF
C?
56uF
R?
402
D?
LED
PIGTAIL



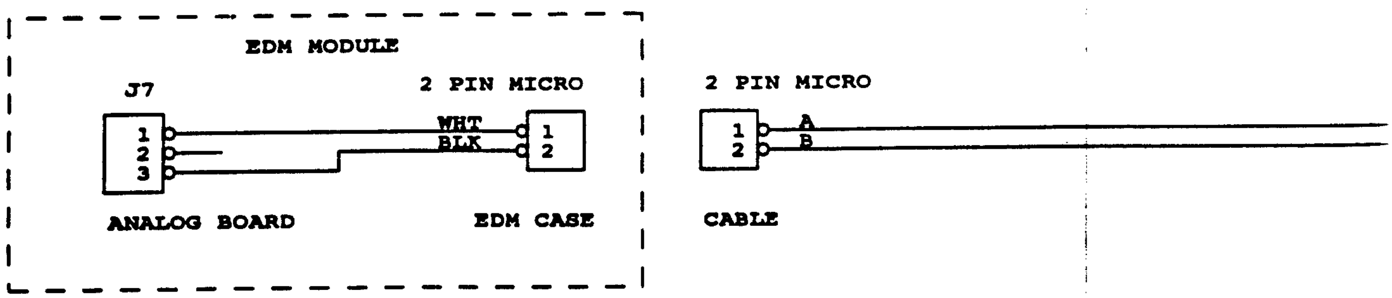
Title Special Purpose Interface Adaptor (SPIA)		
Size B	Document Number QRAT Schematic	REV 4.3
Date: February 5, 1995	Sheet 3 of	6

2

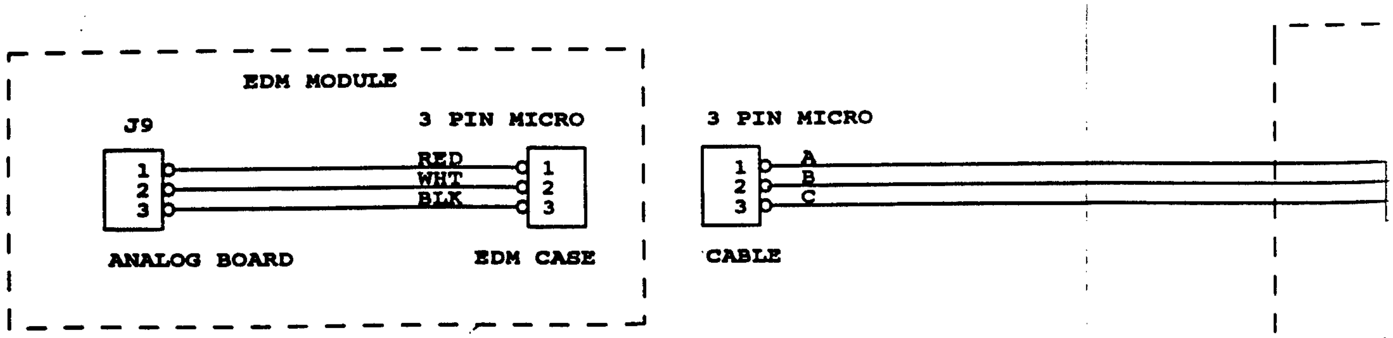
EXTERNAL VIBRATION SENSOR

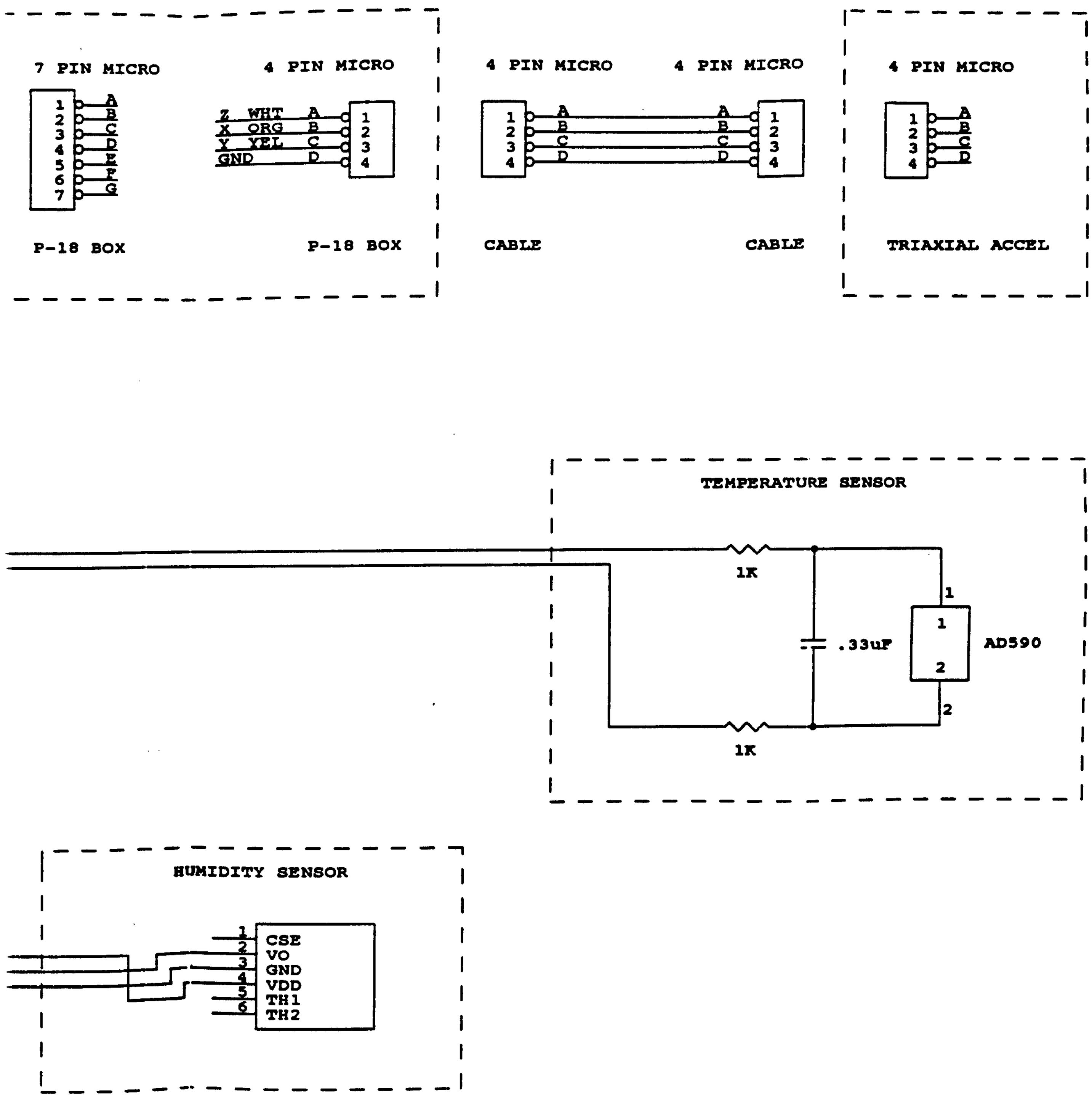


EXTERNAL TEMPERATURE SENSOR



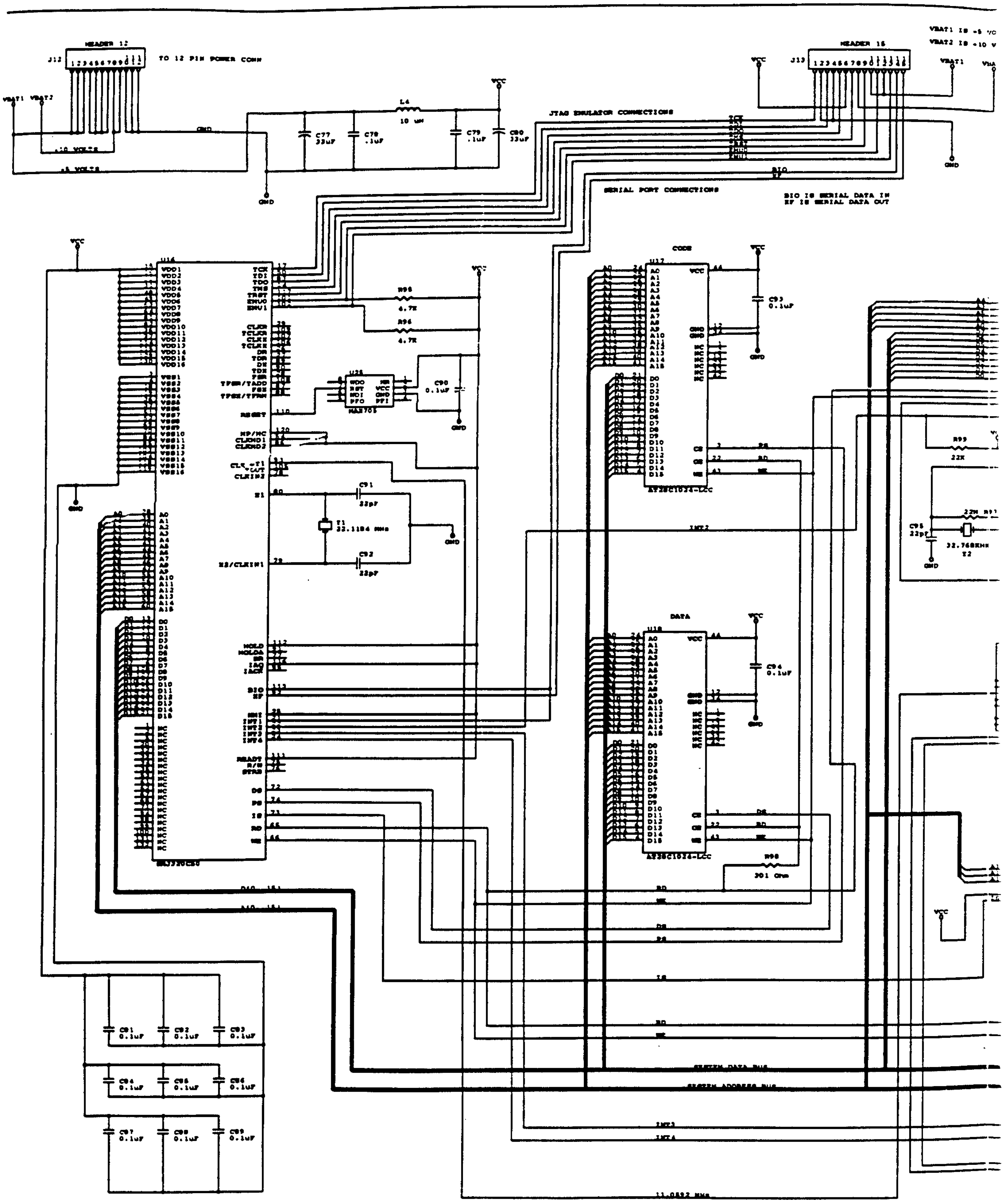
EXTERNAL ANALOG/HUMIDITY SENSOR



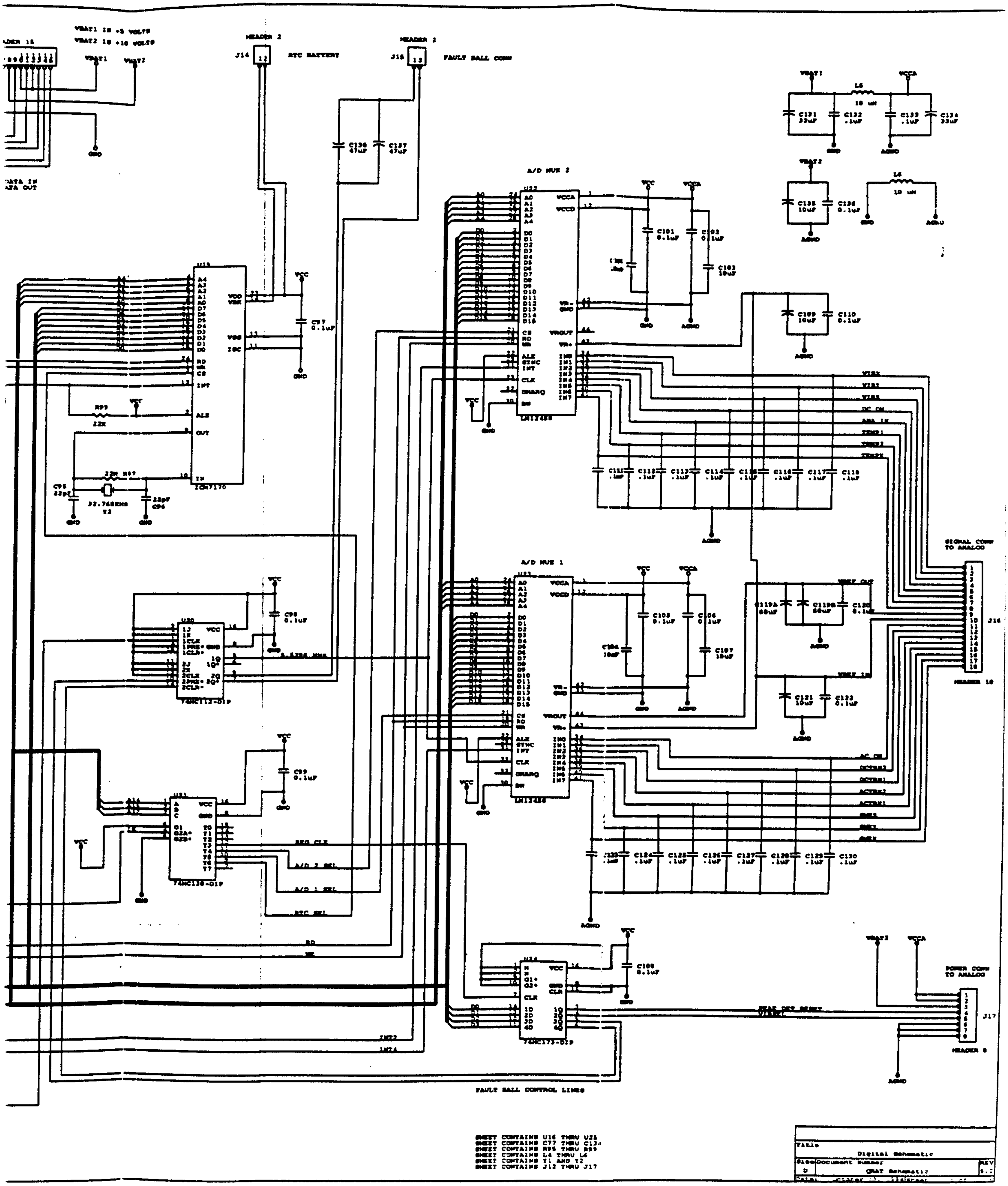


Title		
	External Sensor Circuits	
Size B	Document Number QRAT Schematic	REV 4.1
Date: September 22, 1994	Sheet 4 of 6	

2

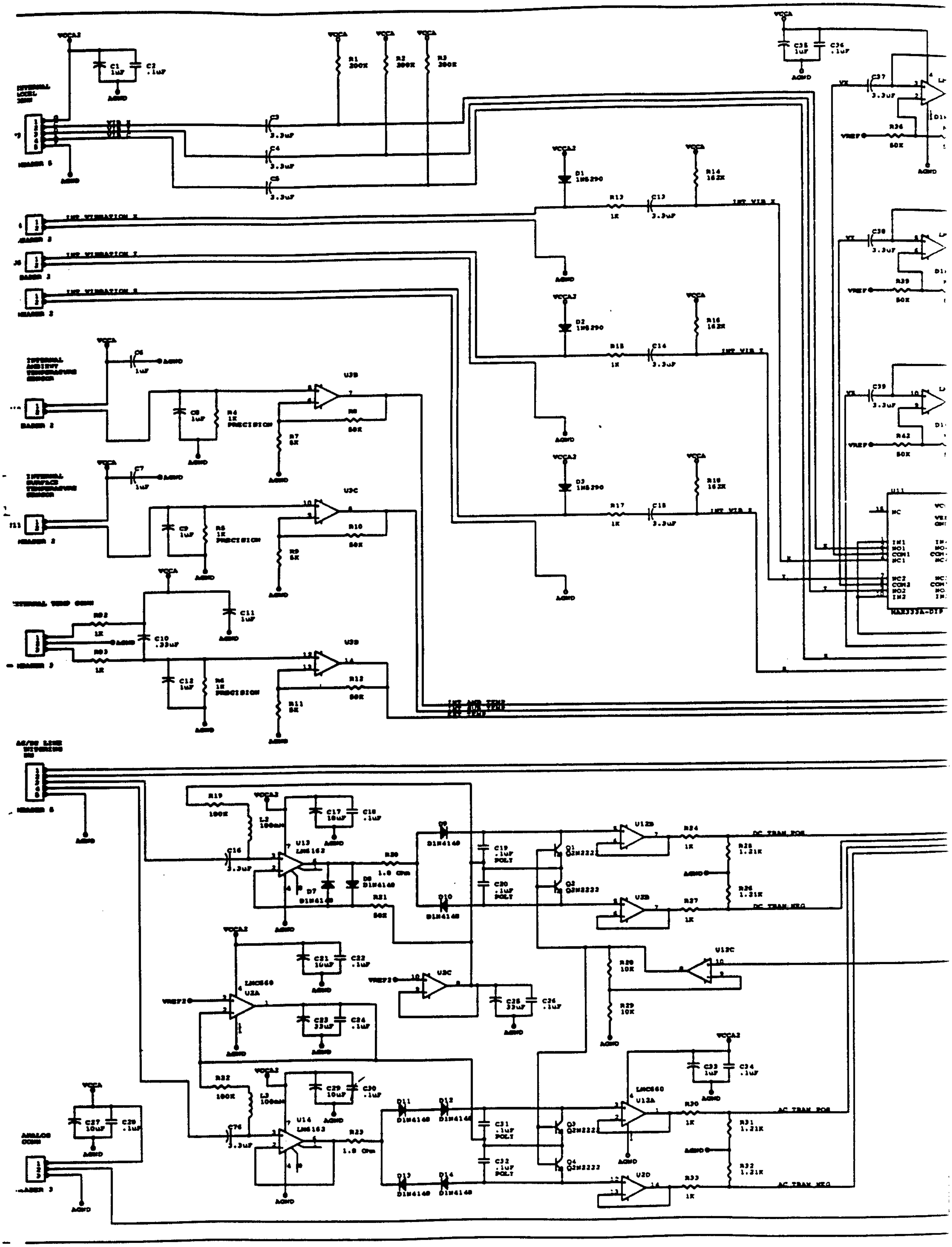

HEADER 12
TO 12 PIN POWER CONN
HEADER 16
JTAG EMULATOR CONNECTIONS
SERIAL PORT CONNECTIONS
DIO IS SERIAL DATA IN
XF IS SERIAL DATA OUT
CODE
DATA
AT28C1024-LCC
AT28C1024-LCC
MAX705
SYSTEM DATA BUS
SYSTEM ADDRESS BUS
11.0592 MHz
32.768KHz
PROCESSOR DECOUPLING CAPS

1



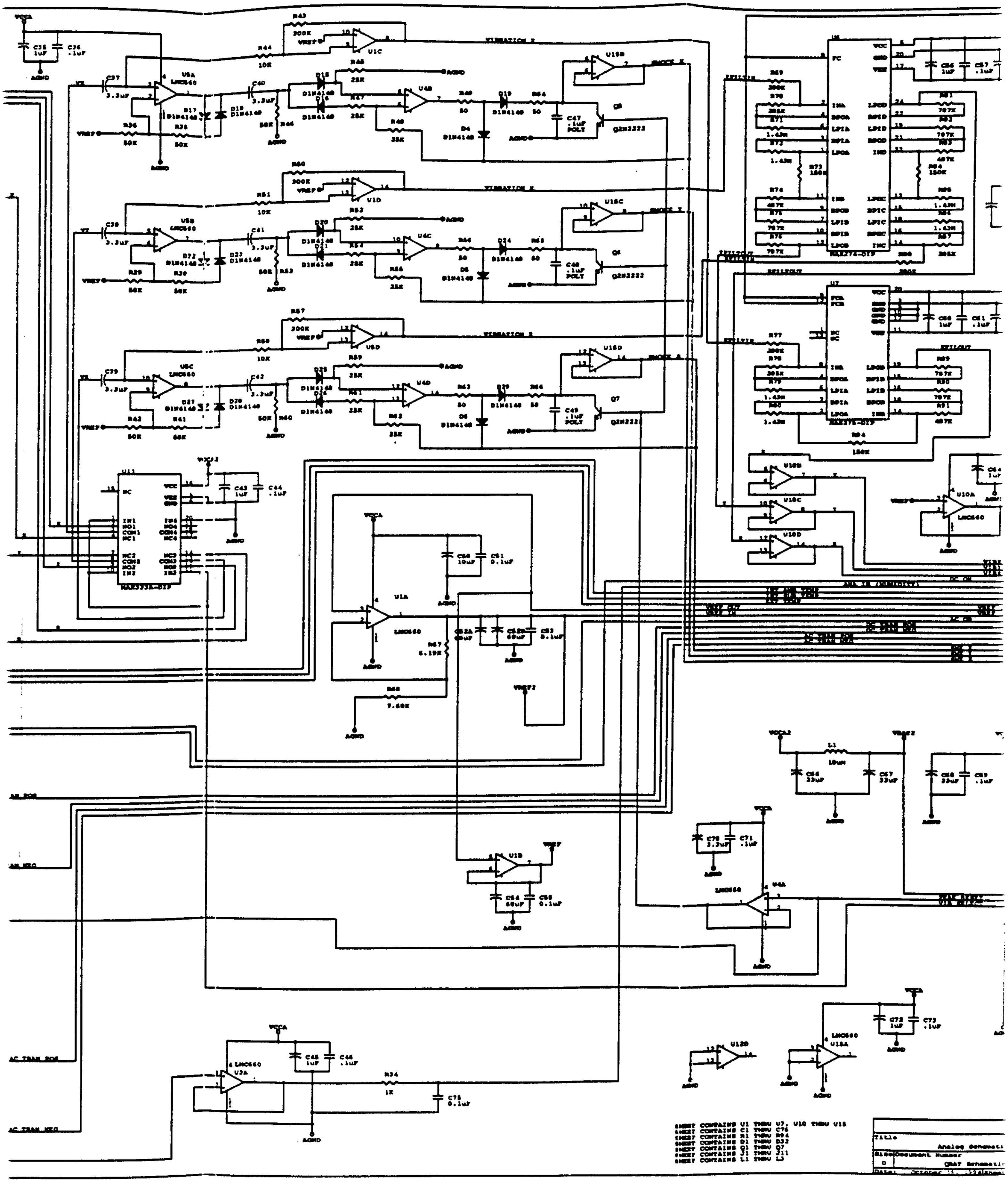
VBAT1 IS +5 VOLTS
VBAT2 IS +10 VOLTS
HEADER 2
J14
RTC BATTERY
HEADER 2
J15
FAULT BALL CONN
VBAT1
VCCA
10 uH
C131 33uF
C132 .1uF
C133 .1uF
C134 33uF
VBAT2
C135 10uF
C136 0.1uF
10 uH
GND
AGND
A/D MUX 2
U22
LM12458
C136 47uF
C137 47uF
C101 0.1uF
C102 0.1uF
C103 10uF
C109 10uF
C110 0.1uF
U19
ICM7170
VCC
C97 0.1uF
R99
22K
C95 22pF
32.768KHz
Y2
22pF
C96
VTBX
VTBY
VTBZ
DC CH
ANA IN
TEMP1
TEMP2
TEMP3
C111 .1uF
C112 .1uF
C113 .1uF
C114 .1uF
C116 .1uF
C117 .1uF
C118 .1uF
SIGNAL CONN TO ANALOG
J16
HEADER 18
A/D MUX 1
U23
LM12458
C105 0.1uF
C106 0.1uF
C104 10uF
C107 10uF
VREF OUT
C119A 68uF
C119B 68uF
VREF IN
C121 10uF
C122 0.1uF
U20
74HC112-DIP
C98 0.1uF
1.8384 MHz
U21
74HC138-DIP
C99 0.1uF
REG CLK
A/D 2 SEL
A/D 1 SEL
RTC SEL
AC CH
C124 .1uF
C125 .1uF
C126 .1uF
C127 .1uF
C128 .1uF
C129 .1uF
C130 .1uF
RD
WR
U24
74HC173-DIP
C108 0.1uF
VBAT2
VCCA
POWER CONN TO ANALOG
J17
HEADER 8
INT2
INTA
FAULT BALL CONTROL LINES
SHEET CONTAINS U16 THRU U25
SHEET CONTAINS C77 THRU C13[illegible]
SHEET CONTAINS R95 THRU R99
SHEET CONTAINS L4 THRU L6
SHEET CONTAINS Y1 AND Y2
SHEET CONTAINS J12 THRU J17
Title
Digital Schematic
Size
D
Document Number
GRAT Schematic
REV

(1)



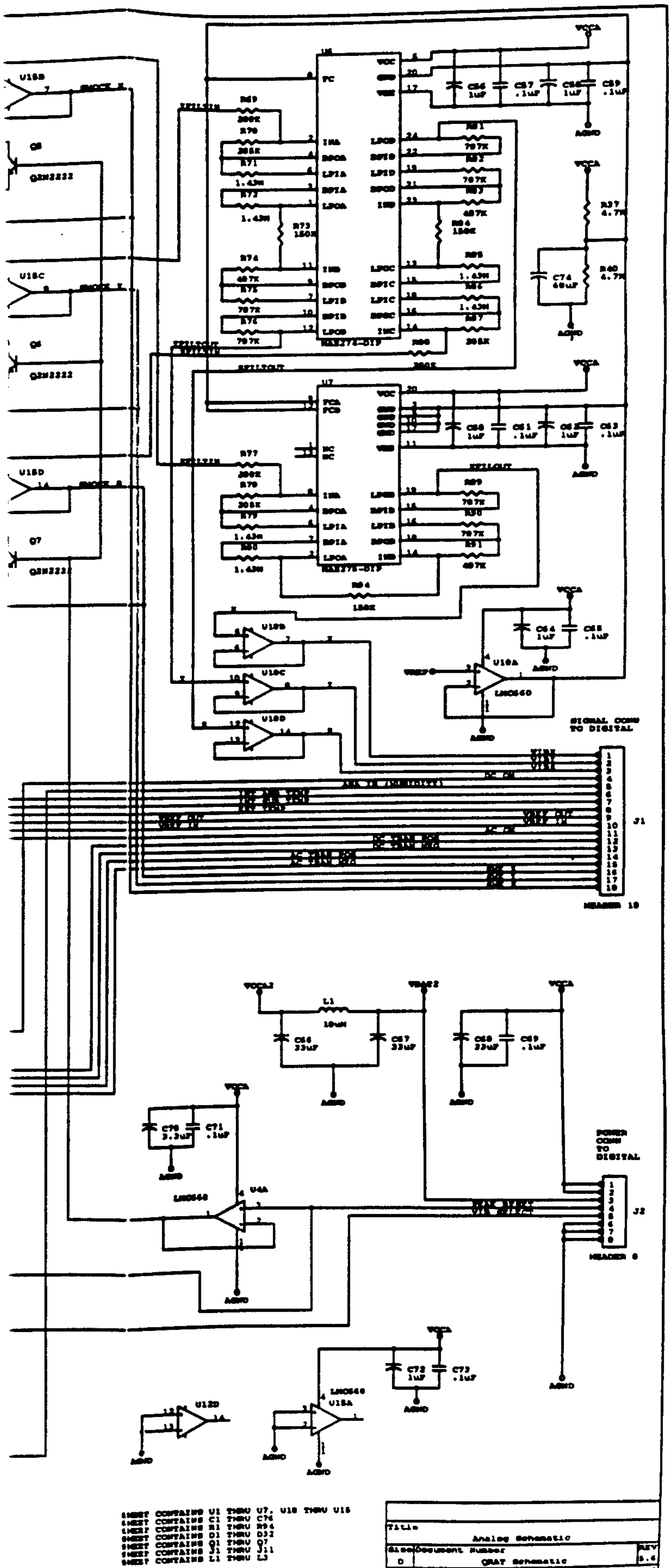
INTERNAL LEVEL CONN
HEADER 5
INT VIBRATION X
INT VIBRATION Y
INT VIBRATION Z
INTERNAL AMBIENT TEMPERATURE SENSOR
INTERNAL SURFACE TEMPERATURE SENSOR
INTERNAL TEMP CONN
INT AMB TEMP
INT SUR TEMP
EXT TEMP
AC/DC LINE MONITORING
ANALOG CONN
DC TRAN POS
DC TRAN NEG
AC TRAN POS
AC TRAN NEG
MAX333A-DIP
LM6162
LMC660
1N5290
D1N4148
Q2N2222

1



VIBRATION X
SHOCK X
LMC660
MAX274-DIP
MAX333A-DIP
Q2N2222
D1N4148
VCCA
VREF
AGND
SHEET CONTAINS U1 THRU U7, U10 THRU U15
SHEET CONTAINS C1 THRU C76
SHEET CONTAINS R1 THRU R94
SHEET CONTAINS D1 THRU D32
SHEET CONTAINS Q1 THRU Q7
SHEET CONTAINS J1 THRU J11
SHEET CONTAINS L1 THRU L3
Title
Analog Schemati
Size
Document Number
D

(2)



SHEET CONTAINS U1 THRU U7, U18 THRU U15
SHEET CONTAINS C1 THRU C76
SHEET CONTAINS R1 THRU R94
SHEET CONTAINS D1 THRU D32
SHEET CONTAINS Q1 THRU Q7
SHEET CONTAINS J1 THRU J11
SHEET CONTAINS L1 THRU L3
Title
Analog Schematic
Size
D
Document Number
QRAT Schematic
REV
5.4
MAX275-DIP
SIGNAL CONN TO DIGITAL
POWER CONN TO DIGITAL
HEADER 18
HEADER 8
J1
J2
VCCA
AGND
LMC660

(3)

Appendix C
List of Acronyms

AC	Alternating Current
A/D	Analog to Digital Converter
A to D	Analog to Digital Converter
ATOD	Analog to Digital Converter
BIT	Built in Test
CMOS	Complimentary Metal Oxide Semiconductor
CR	Carriage Return
DC	Direct Current
DOS	Disk Operating System
DSP	Digital Signal Process (-ing), (-or)
DRAM	Dynamic Random Access Memory
EDM	Exploratory Development Model
EEPROM	Electrically Erasable Programmable Read Only Memory
EMI	Electro-Magnetic Interference
FFT	Fast Fourier Transform
FIFO	First In First Out
IC	Integrated Circuit
JTAG	Joint Test Action Group (bus standard)
LOA	List Of Acronyms
LSB	Least Significant Bit
MIPS	Million Instructions Per Second
PC	Personal Computer
QRAT	Quick Reliability Assessment Tool
RAM	Random Access Memory
RH	Relative Humidity
RMS	Root Mean Square
RTC	Real Time Clock
SOW	Statement Of Work
SPIA	Special Purpose Interface Adapter
TSMD	Time Stress Measurement Device

Appendix D
Review of Zero-Order Data Predictors

Data compression filters are used to compress data into a format more space-efficient for storage. These filters usually reduce the amount of storage space required by reducing the amount of information contained in the data. In general, the more information sacrificed in the compression process, the more space conserved.

Data filters need not actually lose information through compression, and complex algorithms exist that allow the compression and decompression of data sets without information loss. Such algorithms are typically computationally demanding.

The QRAT employs data filters to reduce the amount of information generated by various sensors systems. These reduced data sets are then more efficiently stored in non-volatile memory. Among the vast array of data compression tools exists a subset called **data predictors**. Data predictors define characteristics of data flow based on past information in an effort to predict the value of subsequent elements. If the subsequent elements conform to the prediction model, they can be filtered (ignored) by the system. What remains is the knowledge that the missing element conforms to the prediction model. If the predictor model is chosen wisely, the information loss will not affect the ultimate usage of the recorded data.

In a **zero-order predictor**, a single stream of data is generated by the sensor systems at a synchronous rate. These data vary in magnitude. The predictor model is a simple thresholding of the most recent non-filtered data element. More specifically, thresholds are set at values above and below the magnitude of the current sample. If the next data element lies below the upper threshold and above the lower threshold, the element is filtered (not recorded). Conversely, if a subsequent sample lies outside of the threshold-bounded region, the sample is passed (recorded) and used to generate new values for the upper and lower thresholds. Since the synchronous sample time (time stamp) of each sample is recorded for each data element, the data set can be reconstructed and the filtered values can be estimated to a precision consistent with the prediction model (threshold levels).

The difference between the thresholds and the magnitude of the last recorded element in a zero-order predictor is called the predictor's **delta**, and is typically expressed in the magnitude units of the recorded data. The **sampling rate** (expressed in samples per unit time) determines the rate at which data elements are obtained and processed by the filter.

Figure D.1 below exemplifies the operation of a zero order predictor operating on an incoming synchronous stream of data elements (samples) from a temperature probe. The value of temperature is shown on the y-axis and time along the x-axis. The solid and dashed (alternating at each re-define to show new definitions) mark the upper and lower thresholds as set by the zero order predictor. Data elements marked with an X are recorded, while data elements marked with a simple dot are filtered (not recorded). In this example, the predictor delta is defined as 1/2 degree of temperature (the magnitude separation between the thresholds is equal to two times the predictor delta, or in this case 1 degree C). And so at the time of each recorded sample, the upper and lower thresholds are set one-half degree above and one-half degree below the recorded value.

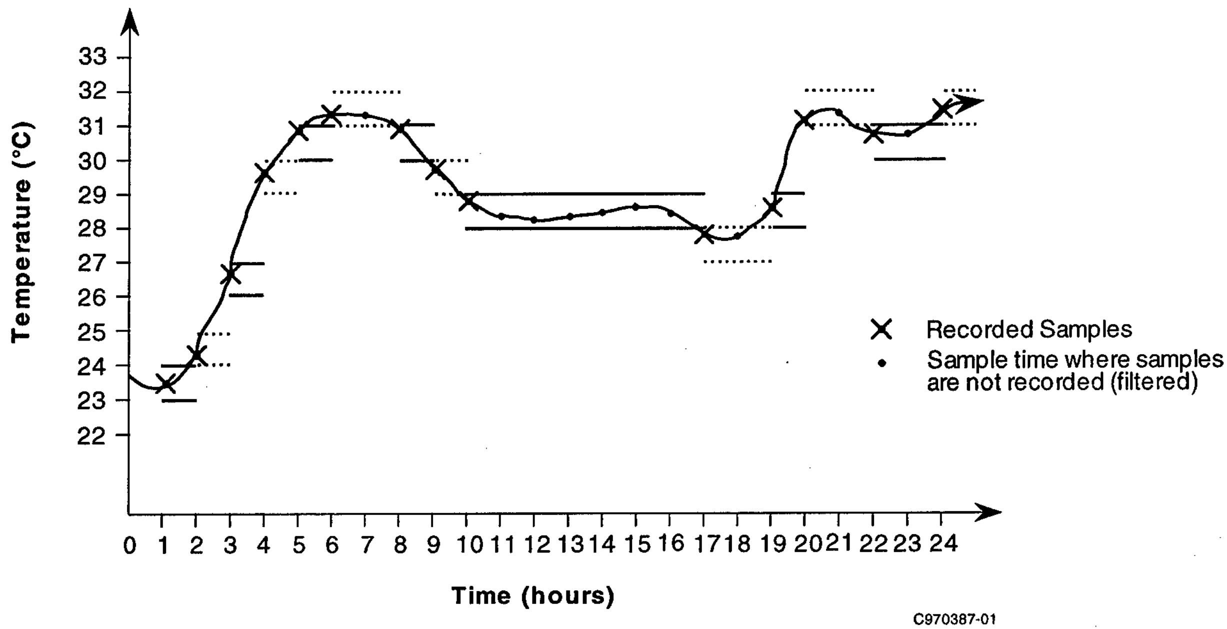


Figure D.1. Sample Operation of a Zero-Order Predictor.

As can be seen in the figure, the six data elements received after the element at time 10 are filtered from the stored data because they do not exceed the predictor delta as defined by sample 10. In general, zero-order predictors are most beneficial where processing power is at a premium and the incoming data has long periods with little variance.

In the case of the vibration recording system on the QRAT, zero-order predictors are employed on the outputs of each of the frequency bins. For a specific bin, say the 1000 Hz bin, the Y-axis of Figure D.1 would be "magnitude of vibration" and the X-axis would remain "time". As the magnitude of the frequency contained in the 1000 Hz bin changed over time, certain samples would be filtered according to the predictor values set for the vibration zero-order predictor. See appendix E for a review of the fast fourier transform.

Appendix E
Review of the Fast Fourier Transform

The inclusion of frequency analysis functions in the QRAT allows for the estimation of the powers density spectrum (frequency domain representation) of a vibration signal. The continuous output of the vibration channels (three independent channels in total) is divided into non-overlapping contiguous regions, and each of these regions is sampled synchronously. These samples form the input to a Fast Fourier Transform (FFT) function. A Fast Fourier Transform is a mathematical algorithm used to efficiently compute the frequency domain equivalent of a time-domain signal. The elements of the frequency domain representation, namely the magnitude of the sinusoids at varying frequencies that when summed form the time domain signal, can be efficiently stored and later used for characterizing the recorded environment.

The Fast Fourier Transform process differs from a mathematical Fourier Transform in that the FFT is performed on discrete or sampled data, and it is accomplished with an algorithm designed for maximum efficiency in a digital signal processor (DSP). The great advantage of this orthogonal transformation is that it allows the analyzing of a signal through knowledge of its constituent parts (sinusoids).

The number of samples used to compute the FFT, combined with the sampling rate used to collect the samples, determines the frequency characteristics of the FFT output. In an FFT, frequency resolution is expressed as a number of frequency **outputs**, **points**, **lines**, or **bins**. For example, if a 400-point FFT examines frequencies to 20kHz, the calculated analysis resolution will be 20,000/400 or 50 Hz per line. The number of output bins is fundamentally matched to the number of input samples or points used in the FFT function.

The overlap between bins is used to advantage in calculations that can determine frequency to an accuracy greater than one bin. These calculations depend on the presence of a single frequency and use a curve fit across adjacent bins to determine exact frequency.

The existence of frequency components at frequencies above one-half of the sampling frequency lead to an overall transformation distortion know as aliasing. These frequencies are attenuated (removed from) in the input signal in the QRAT device through a process known as anti-alias filtering.

☆U.S. GOVERNMENT PRINTING OFFICE: 1998-610-130-61187